MARCH, 1946

The Tech Engineering News

VOL. XXVII, NO. 7 TWENTY-FIVE CENTS

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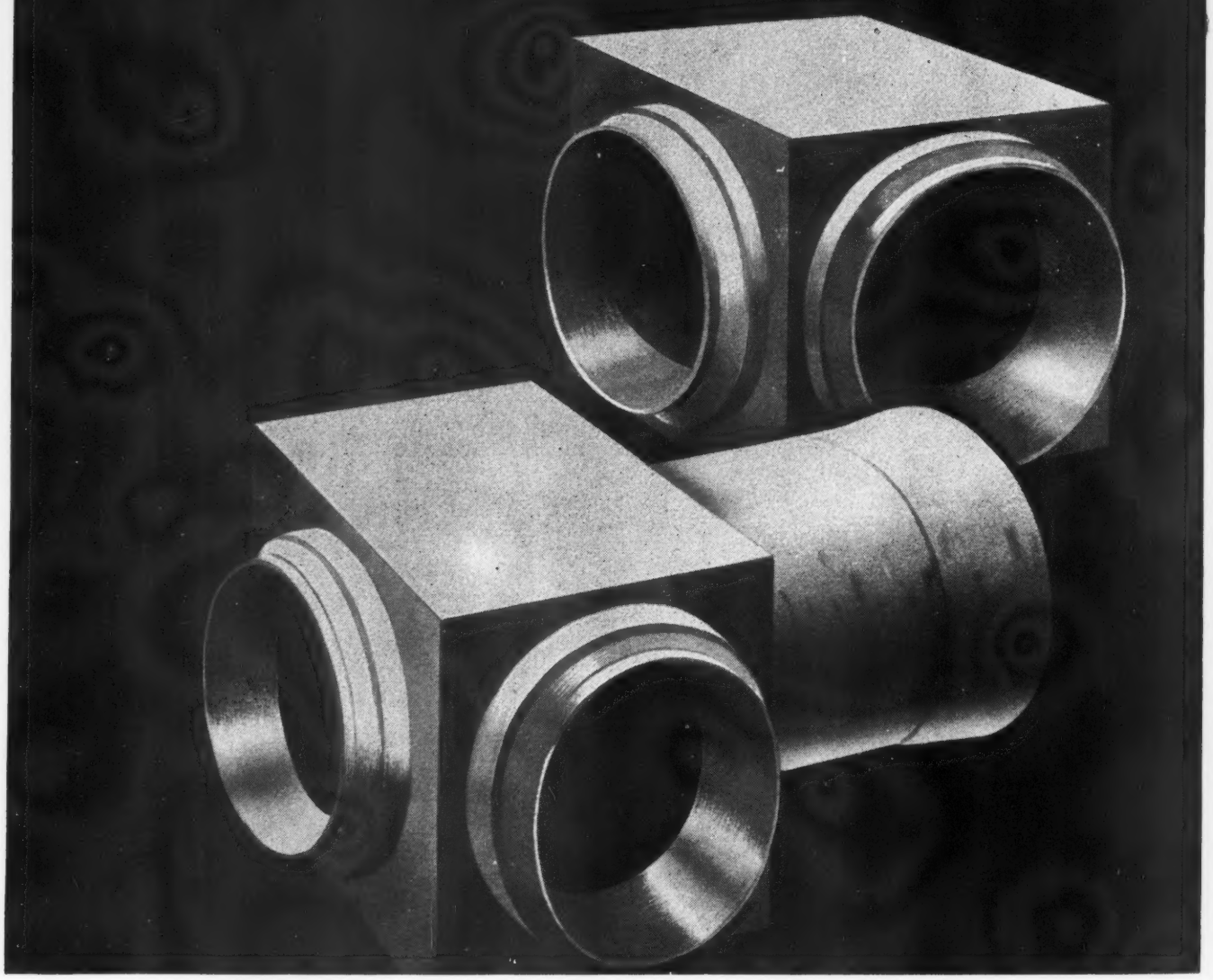

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Du Pont *Digest*

Items of Interest to Students of Chemistry, Engineering, Physics, and Biology

CHLOROPRENE RUBBER DEVELOPED BY DU PONT

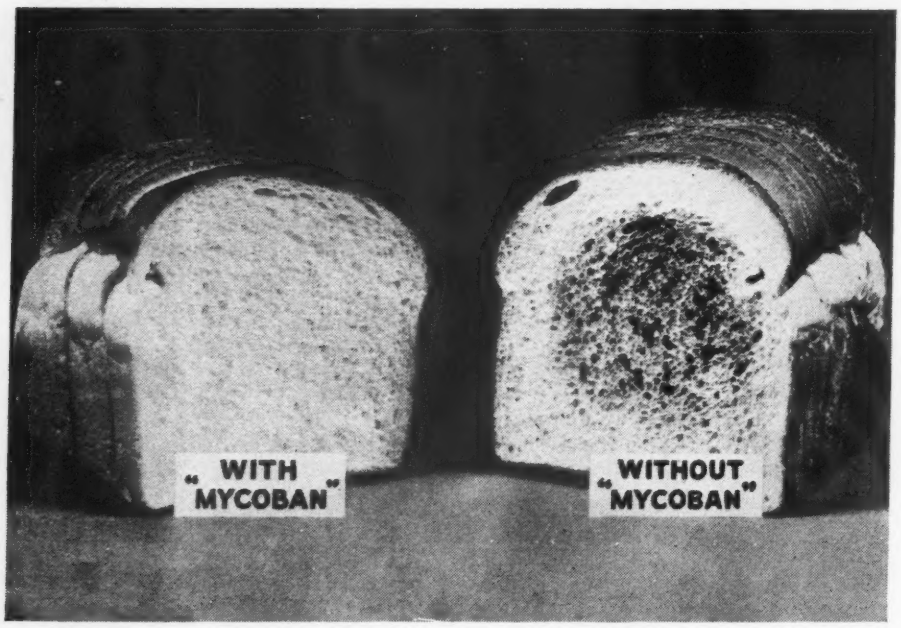
Chemists and Engineers Unite to Produce "Neoprene," Prove Value of Group Research

THE synthesis of rubber was for many years a challenge to the chemists of the world. In 1925 Du Pont chemists undertook to solve the problem, using as their starting point a discovery announced by Dr. J. A. Nieuwland at Notre Dame University in connection with the polymerization of acetylene. The Du Pont research staff modified his process to form a material known as monovinylacetylene and discovered that this, treated with hydrogen chloride gas, produced chloroprene, a chemical previously unknown. Their next discovery was that the polymerization of chloroprene resulted in a rubber-like solid, superior in many respects to natural rubber itself!

Neoprene, as this synthetic rubber is now called, was first placed on the market in 1931. Although more costly than natural rubber, the demand for it grew rapidly. Du Pont engineers were called upon to design and build manufacturing units embodying improved equipment and better production techniques. The result is that today neoprene production is measured in millions of pounds a year, and the price is only slightly higher than that of prewar natural rubber.

The development, the improvement and the large-scale production of neoprene are another tribute to the value of modern, coordinated research. Neoprene is the result of the cooperative efforts of many Du Pont research chemists, engineers and other technical men.

Chemistry extends the mold-free life of baked goods



A hungry world cannot afford to waste bread. Yet until recently millions of pounds of bread were being wasted annually in the United States because of mold. There was a real commercial need for a material that would delay the growth of this food enemy, if only for a day or two. But to meet requirements, this material had to be edible, wholesome, and completely beyond any suspicion of being toxic.

Combined chemical and bacteriological research resulted in the discovery that 0.3% of calcium propionate or sodium propionate in bread would delay the growth of mold for as long as two weeks. In commercial practice, a concentration between 0.1% and 0.2% was found to be sufficient for average conditions.

Calcium and sodium propionates are made from propionic acid, the synthesis of which (from carbon monoxide and ethyl alcohol) is another chapter in the achievements of Du Pont research—and an interesting one. The propionates occur in low concentration in Swiss cheese and other dairy products, as well as in the human body. Hence their consumption in foodstuffs is both natural and safe.

"Mycoban"—as the Du Pont propionates are called—is a shining example of how intensive research solved a problem which long perplexed baking technologists.

More facts about Du Pont—**Listen to "Cavalcade of America," Mondays, 8 PM EST, on NBC**

Questions College Men ask about working with Du Pont

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•

On-the-job training of new chemists and engineers is supplemented at many Du Pont plants and laboratories by training courses, lectures, and conferences. In 37 laboratory centers—chemical, biological, metallurgical, engineering, physical—new men are continually exposed to the thinking and direction of men who have given cellophane, nylon, polythene, and many other products to America.

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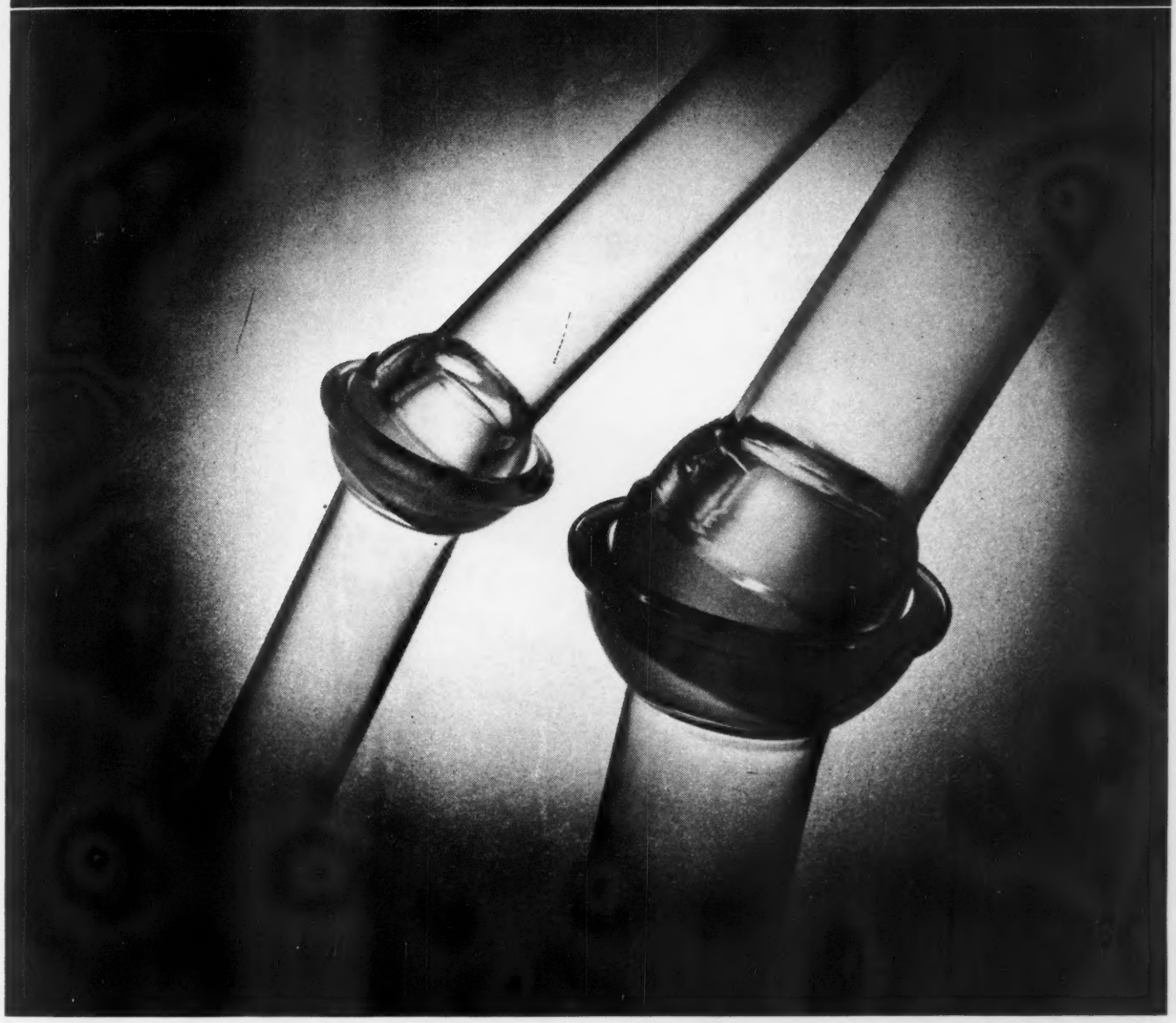
Have you heard about our "Glass Knees"?



THEY look like little knobby glass knees. But to a laboratory worker this jointed glass tubing is a real blessing.

You've seen nightmare arrangements of glass tubing, flasks, and jars in "science" movies. Real laboratories have them, too. And the job of connecting a maze of tubing—with rigid glass joints that slip together like a fishing rod—is a tough one. Everything has to be lined up just right. And then a shock or a blow may break the rigid tubing and you have to start all over again!

So laboratory people weren't displeased when Corning came out with a tough leakproof ball and socket joint. It sets up and takes down easily. Parts are interchangeable, due to precision grinding. And it permits slight movements of the apparatus without leaking or breaking.

The answer to this glass problem was fairly easy Others have been more difficult. The builders of the Lincoln Tunnel in New York wanted glass tiles for walls and ceilings that would reflect light but not glare and wouldn't catch dirt. A man in Berkeley, California, who was building the first "atom" smasher" asked for glass parts that could withstand the terrific heat of 8,500,000 electron volts. Chemical manufacturers needed piping that would resist the corrosive action of hot acids.

Corning research and manufacturing skill solved these glass problems. Keep this in mind wherever you wind up after school. It is entirely possible that the intelligent application of glass to many of your problems may lower costs and raise quality and performance. When the time comes, we'd like to help you find out. Corning Glass Works, Corning, New York.

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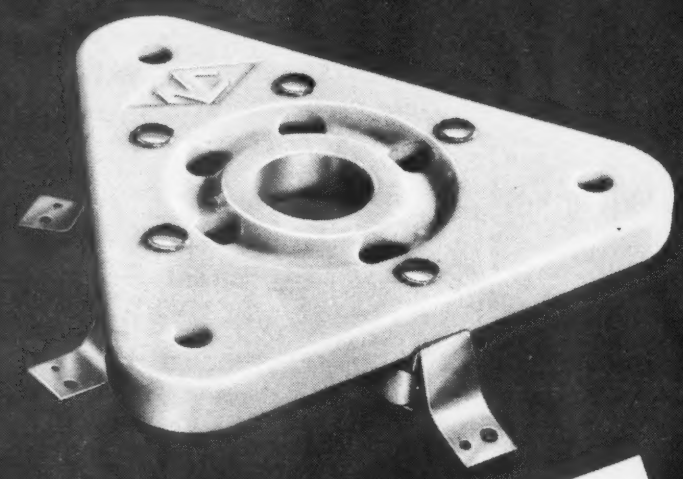

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The TECH ENGINEERING NEWS

PROFESSIONAL JOURNAL OF THE UNDERGRADUATES

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Authenticated News Photo

TITLE PAGE

Natural gas pipe-line is blocked and welded before being laid into the soil

Authenticated News Photo

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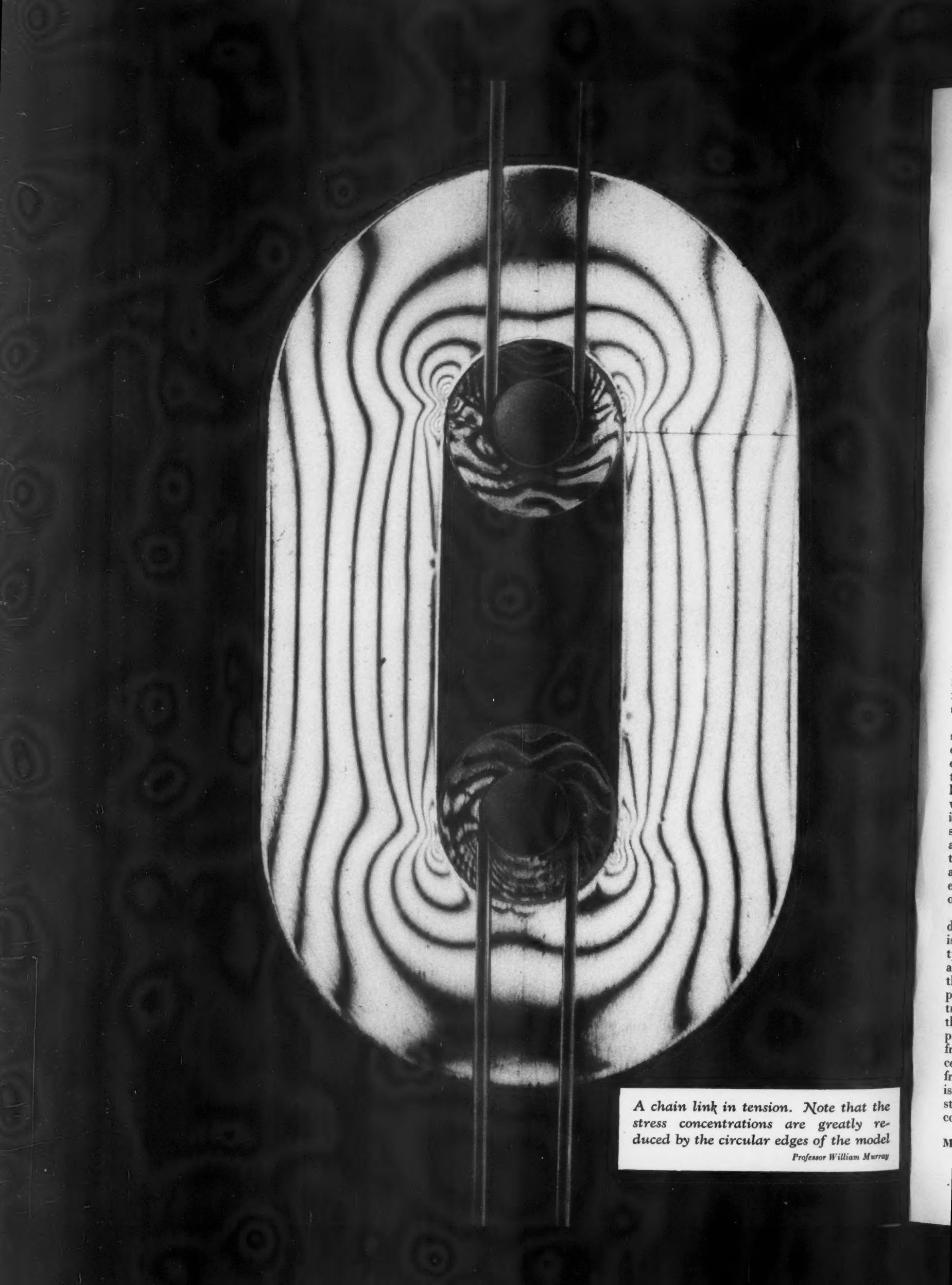


A chain link in tension. Note that the stress concentrations are greatly reduced by the circular edges of the model

Professor William Murray

The Photoelastic Method of Stress Analysis

By JAMES P. COFFEY, 6–46

THE strength and properties of materials under load play an extremely large part in constructional work. It is not too much to say that a study of those branches of science concerned with the distribution of stress in a material is fundamental for engineers who are, for the most part, engaged in the design and construction of appliances capable of bearing relatively large loads and often subjected to stress of much complexity.

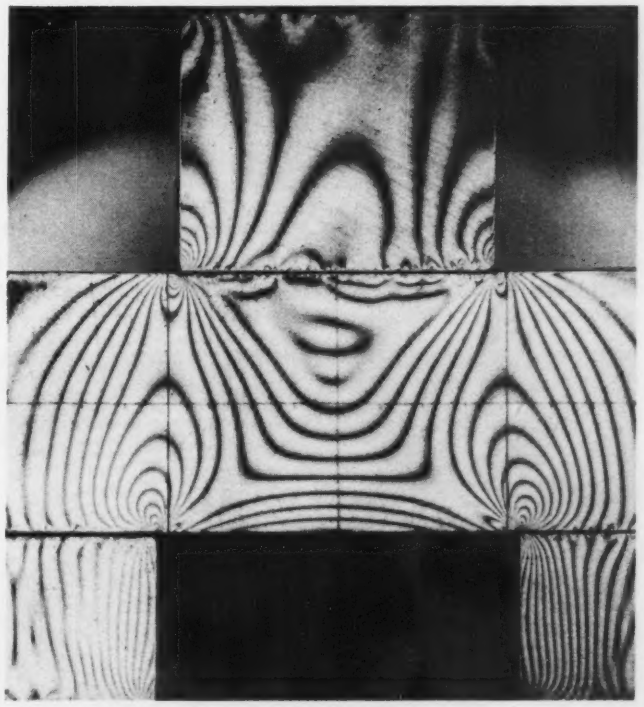
Modern needs and scientific discoveries are always leading to new and more difficult problems in engineering, for which solutions must be found and expressed in the form of definite machines and structures. In most of these problems somewhat complicated stress distribution occurs since the requirements of construction necessarily lead to forms which are not conveniently adapted to mathematical analysis. A large number of solutions of stress distribution in elastic bodies have been obtained and are continually being added to by the labors of mathematicians, yet it seems impossible to keep pace with actual needs by philosophical reasoning alone. As is well known, most of the difficult problems encountered in modern engineering construction have to be solved by bringing to bear upon them all the theoretical and experimental knowledge available, and then utilizing this store of accumulated knowledge, together with practical experience on allied problems, to obtain a safe and economical structure or machine. One of the most useful methods of experimentally attacking a new engineering problem is to examine the properties exhibited by a model of the proposed form in the same or in a different material, under loads bearing a proper scale relation to those to be borne by the full-sized structure. Such methods are employed extensively in research of many kinds.

This treatise will be devoted to another method of stress determination through the use of models. When one is considering stresses in one plane alone the photoelastic method has wide application and utility. Attention was first drawn to the possibilities of this method a little over a hundred years ago by Sir David Brewster who found that stressed glass when viewed with polarized light showed brilliant colors. Very little, however, seems to have been done along these lines until within about the last thirty-five years. Prof. E. G. Coker of the University of London has probably done more than any other single person to further the art of Photoelasticity which at present seems to be enjoying a wave of popularity.

There are many stress analysis problems, called two-dimensional stress problems, in which the deformation is fundamentally parallel to a plane. Examples of this type of stress problem are bending of gear teeth, arches, and girders or plates of varied shapes but of constant thickness with couples or forces acting on them in the plane of the plate. Because of their shape, stress distributions are difficult to obtain analytically and for this reason the Photoelastic method of analysis has proven invaluable. Scale or actual size models are cut from an isotropic material such as glass, bakelite, or celluloid, or other materials, which become doubly refracting under stress. If, now, a beam of polarized light is passed through a transparent model of this type under stress, a picture with dark and light fringes or with colored bands is obtained.

The apparatus employed in the photoelastic method of stress analysis is comparatively simple and is schematically represented in the accompanying diagram. With the apparatus, which operates on Coper's differential principle, one can determine the difference in principal stresses and their direction at all points in the photoelastic model, as well as the individual stresses at the free boundaries of the model. A development of the method of obtaining stress follows a description of the apparatus.

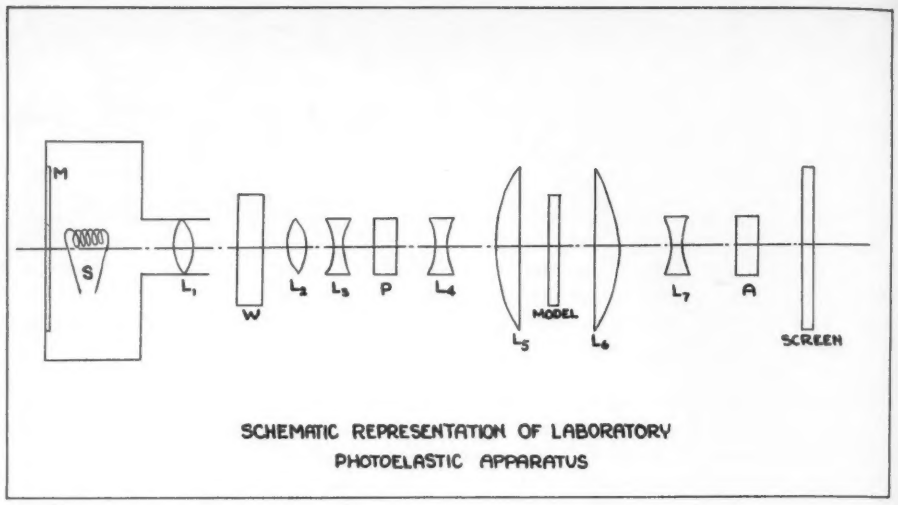
As a light source, *S*, in Figure 1, either a mercury arc (monochromatic) or an incandescent bulb (polychromatic) is used. To make as much use of the light as possible, the source is housed in a chamber and a reflecting mirror, *M*, is placed behind it. A converging lens, L_1, is used to make the beam from the source approximately parallel. *W* is a "water cell," filled with water and a small amount of copper sulphate, which is inserted to eliminate as much heat as possible from the beam of light. After passing through the "water cell" the beam is concentrated by lens, L_2. The beam then passes through a diverging lens, L_3, and into the polarizer, *P*, a Nicols prism, which transforms ordinary random-vibrating light into plane polarized light. The diverging lens is used to decrease the cone angle of the light and enable more of it to pass through the polarizer. The Nicol prism introduces plane-polarized light. Sometimes, however, circularly polarized light is desired. This may be obtained by inserting a quarter-wave plate $\left(\frac{\lambda}{4}\right)$ in the system at this point. The Nicol prism is mounted so that it may be rotated through any



Professor William Murray

A rivet in double shear. Note the large concentrations of stress at the squared boundaries

angle. It is made of Iceland spar crystal cemented with Canada balsam, with the materials so chosen and the dimensions so calculated that plane-polarized light of fifty per cent of the intensity of that entering the prism is produced. Lens L_4 spreads out the beam of light, which is made into a long-parallel beam by the collimated lens L_5. The model, held in a straining frame of any of a wide variety of types, is introduced into the system at this point. The mounting should be capable of motion in the plane perpendicular to the light without changing the load. This is especially desirable if large specimens are to be photographed in sections. L_6 is a large collimating lens used to converge the parallel beam of light passing through the model. L_7 is a diverging lens used for the same reason as L_3 — to get a large portion of the light through the analyzer, A, another Nicol prism. The analyzer affects the polarized light in a manner which depends upon the relative positions of the principal planes of polarizer and analyzer, the passage of light through the analyzer being governed by the vectorial law of resolution. Beyond the analyzer, a camera or ground glass screen may be used to view the resulting image. Of course, if a quarter-wave plate was used on the one side of the model, another one must be used on the other side.

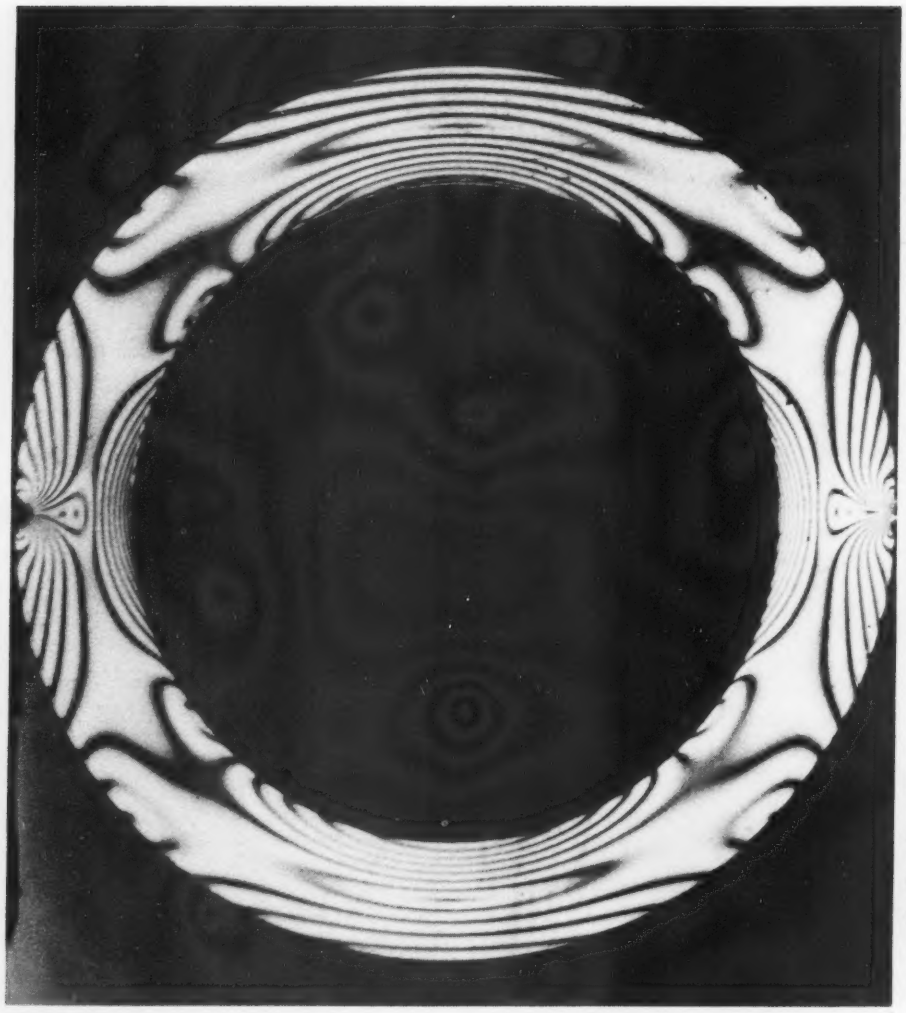


SCHEMATIC REPRESENTATION OF LABORATORY PHOTOELASTIC APPARATUS

Figure 1 — *Diagram by the Author*

A hollow disk subjected to a load at its sides, showing that stress concentrations occur at the point of application of the load, as indicated by the concentration of the isochromatic lines.

Professor William Murray



Since polychromatic light is good only for rough qualitative work, a color filter may be inserted anywhere in the system to obtain monochromatic light. If the filter is mounted in glass, it should be kept outside the polarized region to eliminate photoelastic effects in the glass due to residual stresses and improper annealing and the like.

Having described the laboratory photoelastic apparatus, we now proceed to develop a method of determining the difference between the principal stresses in a photoelastic model under load.

Consider the model element *abcd*, in Figure 2, in which σ_x and σ_y are the principal stresses. The light arriving at O is divided into two components. OA represents to some scale the amplitude and original direction of the plane of vibration. α = the reference angle between the X-direction of principal stress and plane of vibration. On entering the model we note two vibrations:

1. In the X-direction: $a\text{Cos}\, pt\, \text{Cos}\alpha$
2. In the Y-direction: $a\text{Cos}\, pt\, \text{Sin}\alpha$

Where a is the amplitude of the vibration
p is a proportionality factor $=2\pi$ (frequency)
t is time

Let t_1 = time required for light passage in the X-direction
and t_2 = time required for light passage in the Y-direction

Then on leaving the model we obtain:

In the X-direction:
$a\text{Cos}\alpha\text{Cos}\, p(t-t_1)$

(*Continued on page 264*)

Shrivenham Army University

By FRANCIS W. SEARS, '20

Professor of Physics

EDITOR'S NOTE: *Professor Sears, long known around Tech for his vivid lectures in 8.01 Freshman Physics, disappeared into the officially shrouded depths of Europe last spring. As head of the Physics Department at the War College at Shrivenham he spent last summer and fall teaching GI's all about Newton and Bernoulli and their respective theorems.*

"THIS is the I. and E. Division of the Army, calling from the Pentagon. Can you leave for Europe in two weeks to teach in an Army University? We would like your answer in forty-eight hours." Calls like this one were going to men on the staffs of colleges and universities in every State in the Union during the last two weeks of June, 1945. The Army was embarking on a unique type of military operation — the establishment of two universities and a vocational school, with a total enrollment of twelve thousand men, to be set up in the ETO for the benefit of troops awaiting release or redeployment.

The I. and E. (or Information and Education) Division had been functioning since early in the war, and under the direction of Col. Francis T. Spaulding, formerly Dean of the School of Education at Harvard, had organized a program of correspondence courses known as the United States Armed Forces Institute, or USAFI. After the defeat of Germany, and before Japan's surrender had released shipping space that had been earmarked to carry equipment to the Pacific, it appeared that we might have to keep several million men in the United Kingdom and on the Continent for a year or more. Many of these men had partially completed a college career before entering the Army, or were on the point of entering college. The USAFI courses had been so successful that I. and E. decided to expand its program and to offer a wide choice of courses at the college level for the men who were equipped to benefit by them. Instruction would be given by the best staff that could be secured, and in an atmosphere as nearly resembling that of an American college as was consistent with military considerations.

The possibilities of the project were apparent to all who were asked to have a part in it, and in spite of the short notice and the necessity of making up one's mind overnight, a group of one hundred and fifty professors, on leave from some sixty or seventy institutions, struggled up the gangplank of the *Queen Elizabeth* in the evening hours of July 4. Most of us were assigned to the school in England, but a few were to go on to our sister institution in Biarritz, which was not to open until a month later. The rest of the Biarritz staff, as well as that of the technical school at Warton, near Liverpool, followed on the next crossing of the *Elizabeth*, two weeks later.

In 1937 the British had built a training school for artillery officers, taking over for the purpose a large country estate located in Shrivenham, a town about sixty miles west of London and twenty miles southwest of Oxford. There they had built four large barracks buildings of red brick which, with a number of smaller houses for married men and for officers, could accommodate about five thousand men. When our troops began to arrive in England in 1942 the entire establishment was taken over by the United States Army and was used by us throughout the war for training schools of one sort or another. These schools were closed down after VE Day, and the buildings were turned over to Shrivenham American University. (Originally, the official designation of the Shrivenham school was "Army University Center No. 1," and that of the school in Biarritz was "Army University Center No. 2." General McCrosky, in charge at Biarritz, was liberally endowed with the old school spirit and insisted that his school was not going to be a number two of anything. He therefore changed its name to "Biarritz American University," and Shrivenham

Watson East — classrooms and offices

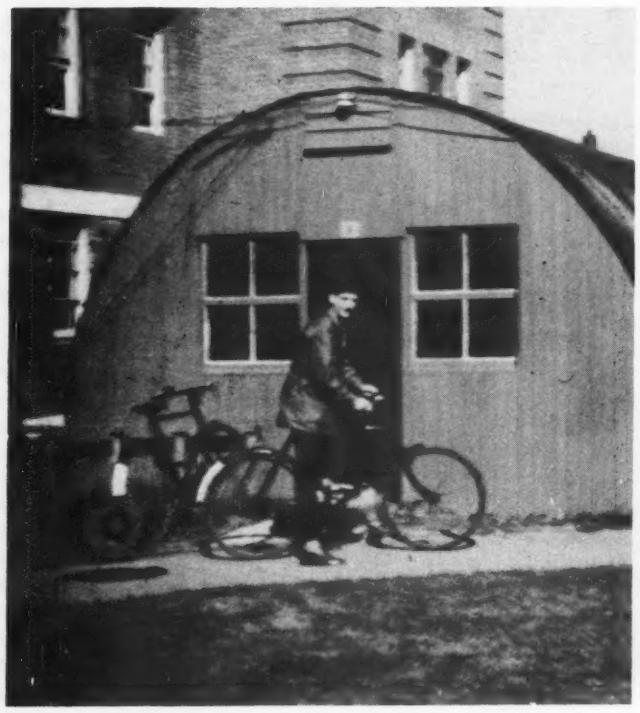
gracefully followed suit.) The village of Shrivenham lies in White Horse Vale, on the border of the counties of Wiltshire and Berkshire and just north of the Downs. The nearest city of any size is Swindon, about ten miles distant, with a population of about fifty thousand. Shrivenham is a typical picturesque English village, with stone houses, thatched roofs, a Norman church, and a couple of pubs that serve warm, flat, tasteless, and kickless beer. The surrounding countryside is slightly rolling and is one of the most prosperous agricultural and dairying sections in England. The farms are small, and the fields are separated by hedgerows interspersed with an occasional elm or oak.

Looking northeast from the tower

The first contingent of instructing staff landed at Greenock, Scotland, on July 10 and reached Shrivenham on the following day. Classes began on August 1. The task of organizing a curriculum, constructing laboratories, and obtaining equipment, was in some way or other accomplished during the intervening fortnight. Approximately one thousand German PW's were assigned to the camp, quartered in tents within a barbed wire stockade. These were our source of manual labor, and provided the carpenters, electricians, plumbers, painters, cooks, waiters, and so forth. All were extremely proud of their skills and, once they understood what was required, would go to work with the obvious aim of demonstrating to us how well such things were done in Germany.

Of the four large barracks buildings, three were used as "dormitories" by the students while the fourth housed the library, offices, classrooms, and laboratories. A number of smaller buildings scattered over the campus were also available for classrooms. The officers and teaching staff lived in the houses that had been built as officers' quarters, and the permanent cadre occupied another group of houses where the British had quartered their married enlisted men. The total population, including the PW's, was in the neighborhood of six thousand men.

The Physics headquarters and Professor Sears



At the head of the military establishment was Maj.-Gen. Claude M. Thiele, formerly in command of our anti-aircraft defense in the United Kingdom. The "president" of the school, in a civilian sense, was Prof. Elmer T. Peterson, on leave from his position as Dean of the School of Education at Iowa State. In addition to the civilian instructors who had been recruited in this country, about a hundred Army officers, formerly college teachers, were released from duty in England and on the continent and assigned to the teaching staff.

With the exception of courses in medicine and law, practically every subject in the college catalogue was offered at SAU. The faculty was subdivided into "Sections" in Liberal Arts, Fine Arts, Engineering, Science, Agriculture, Economics, and Education. Each of these, in turn, comprised a number of "Branches." The Science Section, for example, included branches in Chemistry, Physics, Mathematics, Biology, and Geology. The only prerequisite for admission was that a man should be a high school graduate. However, about three-quarters of the student body had completed one or more terms of college work, and a sizable number already had college degrees. The majority were enlisted men, with a sprinkling of officers and even a few WAC's.

Men were assigned to the school for a term of eight weeks. In such a short time, of course, no continuing program of study was feasible and everyone was free to select any subject for which he was prepared. Most courses met for one hour a day, five days a week. (No Saturday classes.) A minimum of two and a maximum of three courses was permitted. Physics was a "double course," meeting in theory for ten hours a week. Actually, with two two-hour laboratory periods and the inevitable Friday morning quiz, a total of thirteen class hours per week was available for Physics. Thus in eight weeks most of the material in the average college course in Physics could be covered.

The Army made available many opportunities for

(*Continued on page 262*)

Cold Heat

By HENRY L. LEE, 2-47

CAN one end of a short piece of metal be heated white hot so quickly that the other end does not have time to get warm? Metals conduct heat rapidly, but high frequency magnetic fields enable the engineer to heat localized areas of conductors quickly without appreciably changing the temperature of the remainder of the material.

Electrical conductors are good thermal conductors, and it is difficult to heat a sharply defined area without a large amount of heat being conducted away and being used to heat the rest of the body that is under treatment. The problem of heating conductors is quite opposed to that of heating non-conductors. Non-conductors do not transfer heat readily and are difficult to heat uniformly; conductors transfer heat rapidly and are, except in cases involving a body of relatively large mass, difficult to heat in any way other than uniformly. High frequency techniques have enabled the engineer to overcome the major difficulties of heating both types of materials. The heating of conductors by high frequency magnetic fields is called induction heating. The heating of non-conductors by high frequency fields is called dielectric heating. Dielectric heating will not be discussed here.*

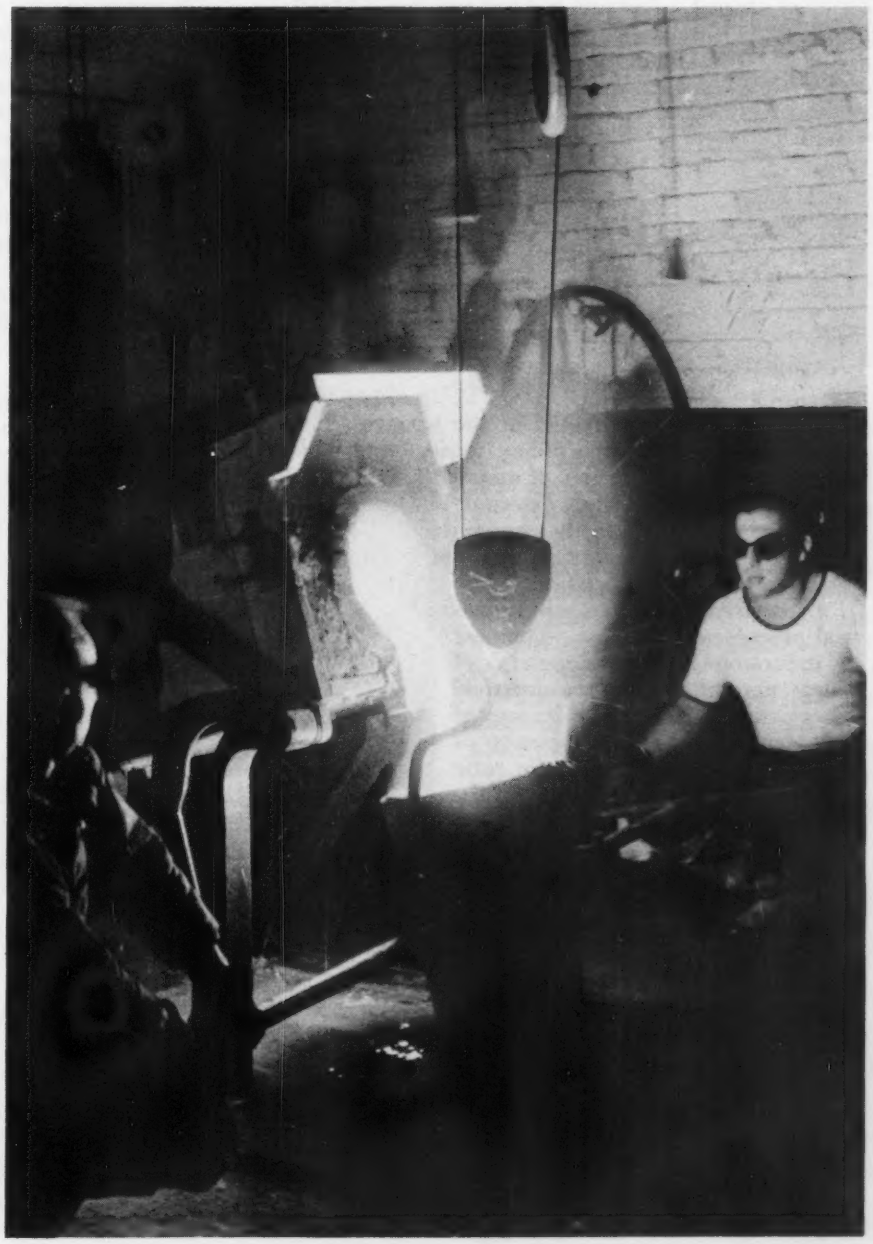
The principles of high frequency heating may be best seen from the examination of a conducting material exposed to a high frequency magnetic field. The material to be heated, usually called the charge, is placed in a coil or solenoid where it is exposed to the greatest strength of the alternating field. Figure 1 shows a schematic arrangement of such a situation.

The alternating magnetic flux of the field induces voltages within the charge; these voltages give rise to small electric currents called eddy currents. The resistance of the conductor to the eddy currents causes a heating effect measured by i^2r. Heat may also be produced by hysteresis when the substance being treated is a ferromagnetic material below the Curie point, but such heating is usually negligible. Induction heating then is caused by inducing electrical currents within the charge.

Using a round stainless-steel bar, the varying effect of frequency on depth of heat penetration may be studied. Figure 2 shows a graph of magnetic intensity, current density, and heat density for three different frequencies. In the first case, if the magnetic intensity is assumed constant throughout the sectional view, the induced voltages are proportional to the square of the radius r. The eddy currents are proportional to the voltages and inversely proportional to the resistance of the individual paths of the eddy currents. Since voltages increase with the square of the radius, and the resistance of the individual current paths is proportional to the radius, the eddy current density varies linearly with the radius (Figure 2b.) At the center of the charge the eddy current density is zero and at the surface of the charge reaches its highest value. The rate of heat generation is

The oldest industrial use of induction heating — melting small batches of metal

Westinghouse



*For a discussion of dielectric heating, see *The Tech Engineering News*, February 1946, Dielectric Heating, H. L. Lee.

proportional to the square of the eddy current density, hence the distribution of heat is parabolic. (Figure 2c)

In cases two and three the frequency has been increased to values such that the opposing magnetomotive forces defined by Lenz's law and generated by the eddy currents are no longer negligible, but effectively oppose and reduce the magnetic intensity within the charge. The reduction of the magnetic intensity causes a corresponding decrease in current density and heat intensity. It may be seen in Figure 2i that the heat is

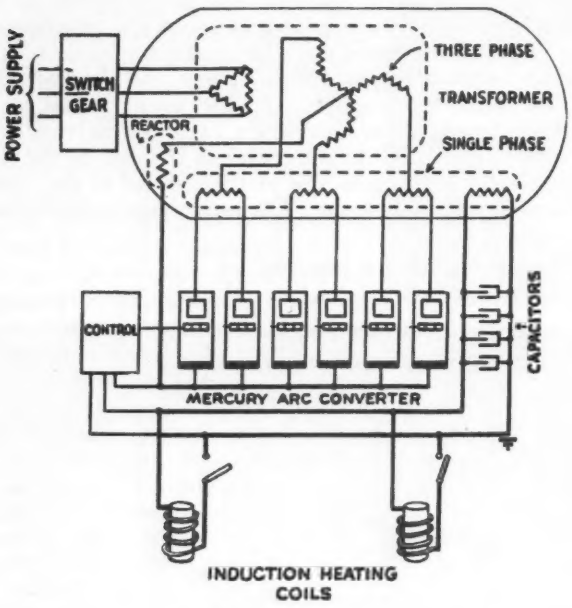


Figure 1. A complete layout for induction heating with mercury arc converters

almost entirely concentrated in the surface. Thus we may conclude that the use of low frequencies enables the engineer to heat the center of metals quickly and without the use of exorbitant external temperatures. The heat is generated within the charge itself. Using higher frequencies enables the engineer to concentrate heat in very sharply defined surface areas.

Of extreme importance in industrial processes is the cost. The cost of induction heating depends, of course, upon the cost of the electrical energy supplied and the efficiency of heat generation. The efficiency of high frequency heating is the ratio between the heat generated in the charge and the energy which is taken from the supply line. This is specifically the over-all efficiency. The over-all efficiency is the product of two factors, the inductor efficiency and the conversion efficiency. The inductor efficiency denotes the ratio between the heat generated in the charge and the amount of energy delivered to the field. Conversion efficiency is the ratio between the power delivered to the field and the power supplied from the line. To date the highest inductor efficiency obtainable is sixty-five per cent regardless of the operating frequency.* Conversion efficiency depends upon the equipment used and is higher in value.

The application of induction heating to a given problem requires a certain amount of study and a supply of knowledge partially derived from experience. In deciding if induction heating is more efficient than other equipment, there are various factors that may be considered. Assuming an adequate source of electrical power and correct application of equipment, the general advantages of induction heating may be seen to be:

1. A rapid rate of heating. The heat is generated in the exact place in the material that it is desired and there is no need to wait for a temperature gradient to be established. Indeed, it is possible to heat a localized portion of the material and conclude operations before a temperature gradient of any consequence has been established. There is no need for high external temperatures that might damage the outside when attempting to heat the inside to a certain temperature. The damage caused by scaling is greatly reduced.
2. An accurate and instantaneous control of heat supply. Temperatures may be obtained very accurately and small variations are possible if desired. The power is on only when it is needed, and there is no extra expenditure of energy.
3. There is no need for physical contact between the material being heated and the electrical apparatus. Unnecessary separation of charge and coil decrease the conversion efficiency however.
4. The equipment does not require any heavy foundations and can be installed in most plants without too much concern over building design details.
5. No ventilation or air filtering apparatus is requires. There is no fuel dust.
6. Quiet operation.
7. Reasonable maintenance costs, depending upon the equipment.

Examination of the metallurgy of metals treated with high frequencies shows a difference in crystalline structure. Induction heating causes a homogeneous structure of nodular (spherical) crystals whereas furnace treated metals are composed of articular (needlelike) crystals. The structure caused by the

* *Allis Chalmers Electrical Review*, March 1945.

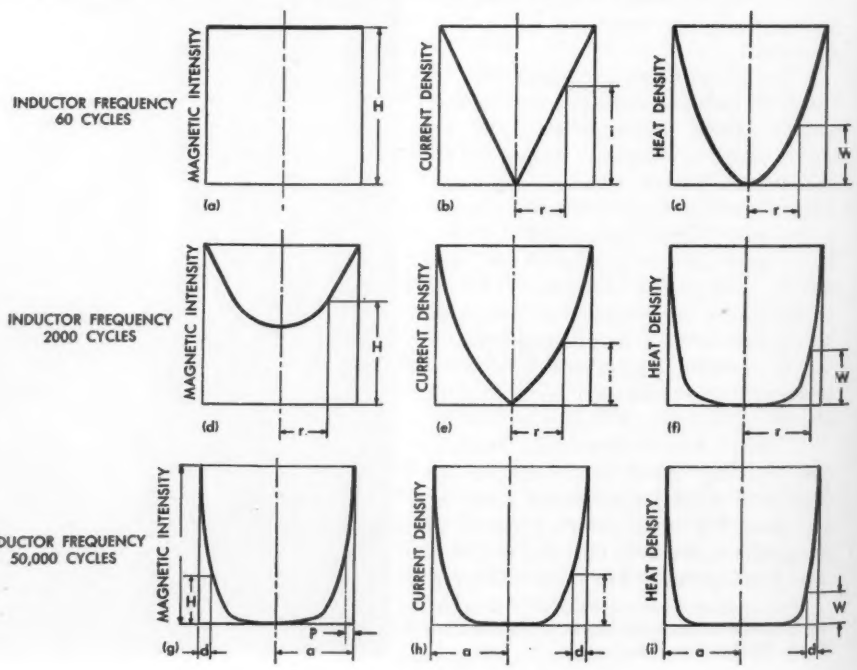


Figure 2 *Allis Chalmers Mfg. Co.*

induction treatment is to be desired as it imparts a stronger texture and lengthens the effective life of the metal. Cracking and chipping are reduced.

Most induction heating apparatus is a combination of generator and quenching units. The quenching of the metal takes place almost instantly after induction treatment and oxidation is reduced to a thin surface scale. In some cases, where necessity demands, all oxidation may be eliminated.

The rapid heating of localized areas eliminates to a large degree the usual distortion caused by heating the whole body.

Of great value is the detection of small cracks or excess porosity in the metal. The porosity or cracks disturb the induced eddy currents and cause overheating in that area. This overheating is quite evident and defects that might have been discovered only by microscopic or magnetic inspection are readily caught early in the processing.

Of great value to some is the ability to treat metal surfaces to any depth with any degree of hardness desired without changing the original properties of the rest of the metal.

The applications of induction heating are numerous and may be divided into four groups. These are the surface or deep hardening of gears, splines, shafts, and parts of production subject to wear; the brazing and soldering of tool tips, contact studs, armature bars, and hundreds of fabricated articles; the annealing of rods, tubes, and the like; and the melting and forging of small articles. Much special equipment has been designed to handle the charge before and after introduction to the magnetic field. Figures 3 and 4 show schematic diagrams of such equipment.

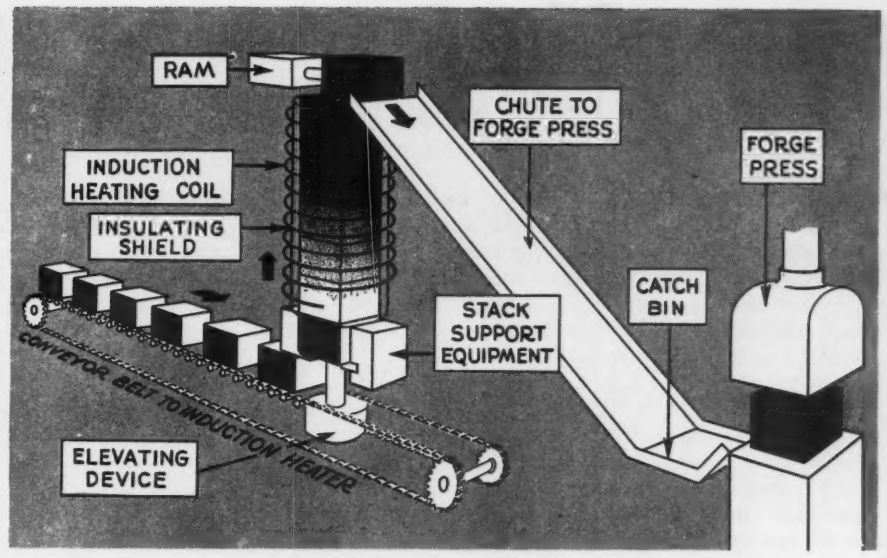


Figure 3. Automatic handling used to load steel billets into induction heating coil for heating prior to forging

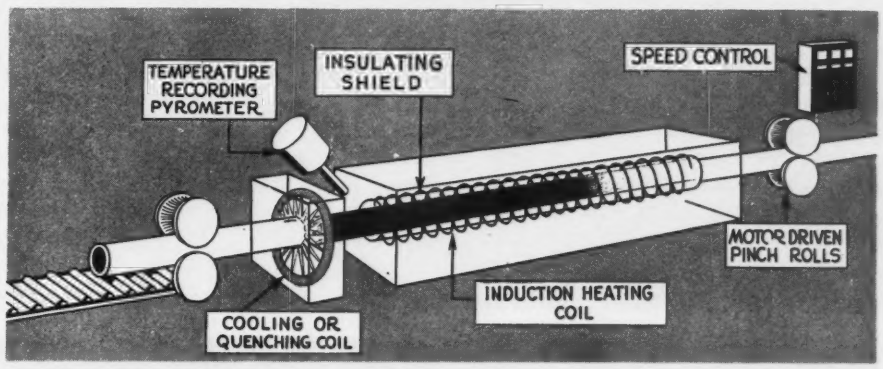
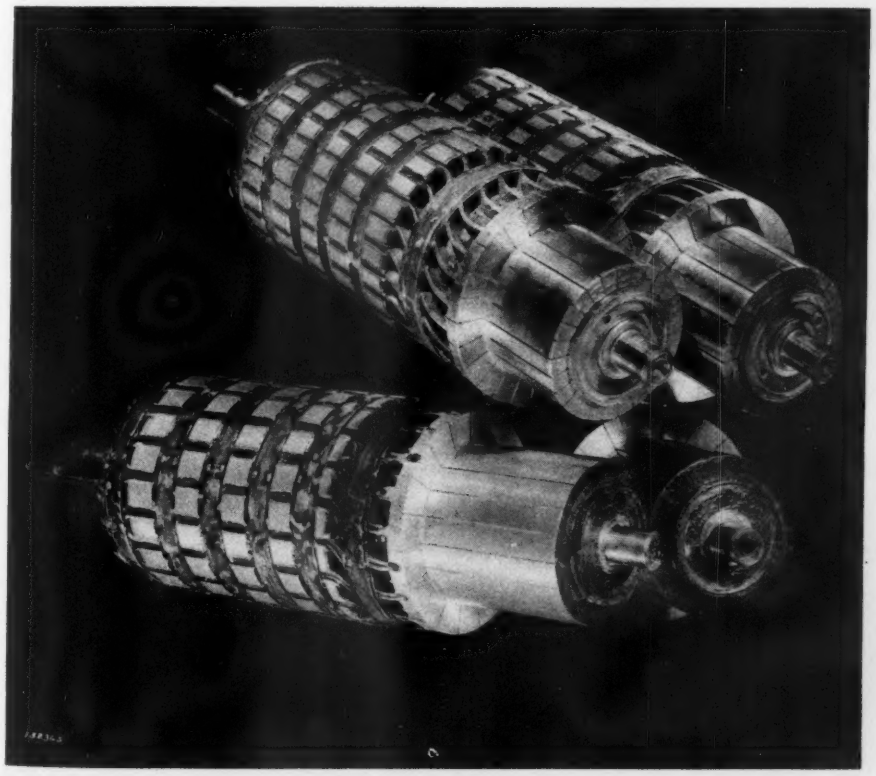


Figure 4. Annealing steel tubing

The trend of modern heating methods in some fields seems to be towards electrical techniques, and it may be expected that new applications will be found by those having specific heating problems.



Motor armatures have proved to be better, both electrically and mechanically, when joints between armature coil and commutator bars are brazed by induction heating.

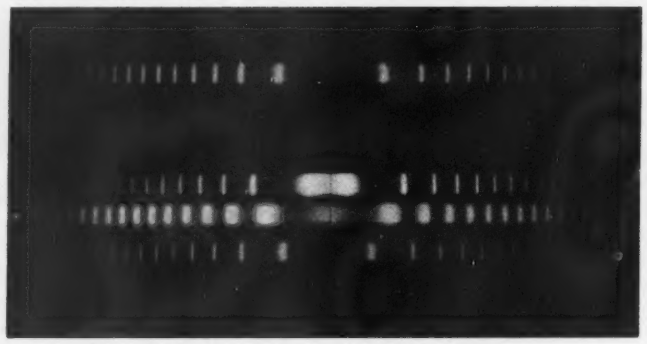
Allis Chalmers Mfg. Co.

The Spectroscopy Lab

By F. FAUSTEN MARK, 2-47

THE importance of the science of spectroscopy fully justifies the care and excellence that went into building and equipping the Spectroscopy Lab. Both the chemical and physical sciences realize this importance, because the applications of this use of optics extend into many fields where it proves to be a relatively uncomplicated technique for obtaining remarkably accurate data. M. I. T.'s lab, built in the early 1930's is one of the best of its kind.

Neon, krypton, and helium spectra *Staff photo*



To enter the lab one must pass through several sets of heavy doors. The function of this arrangement of doors is to keep the constant temperature maintained inside the lab from being affected. The temperature is recorded and controlled by one machine. This control is connected to an air-conditioning system which regulates the humidity as well. It is but one of the many precautions taken in order to insure the best working and most uniform conditions.

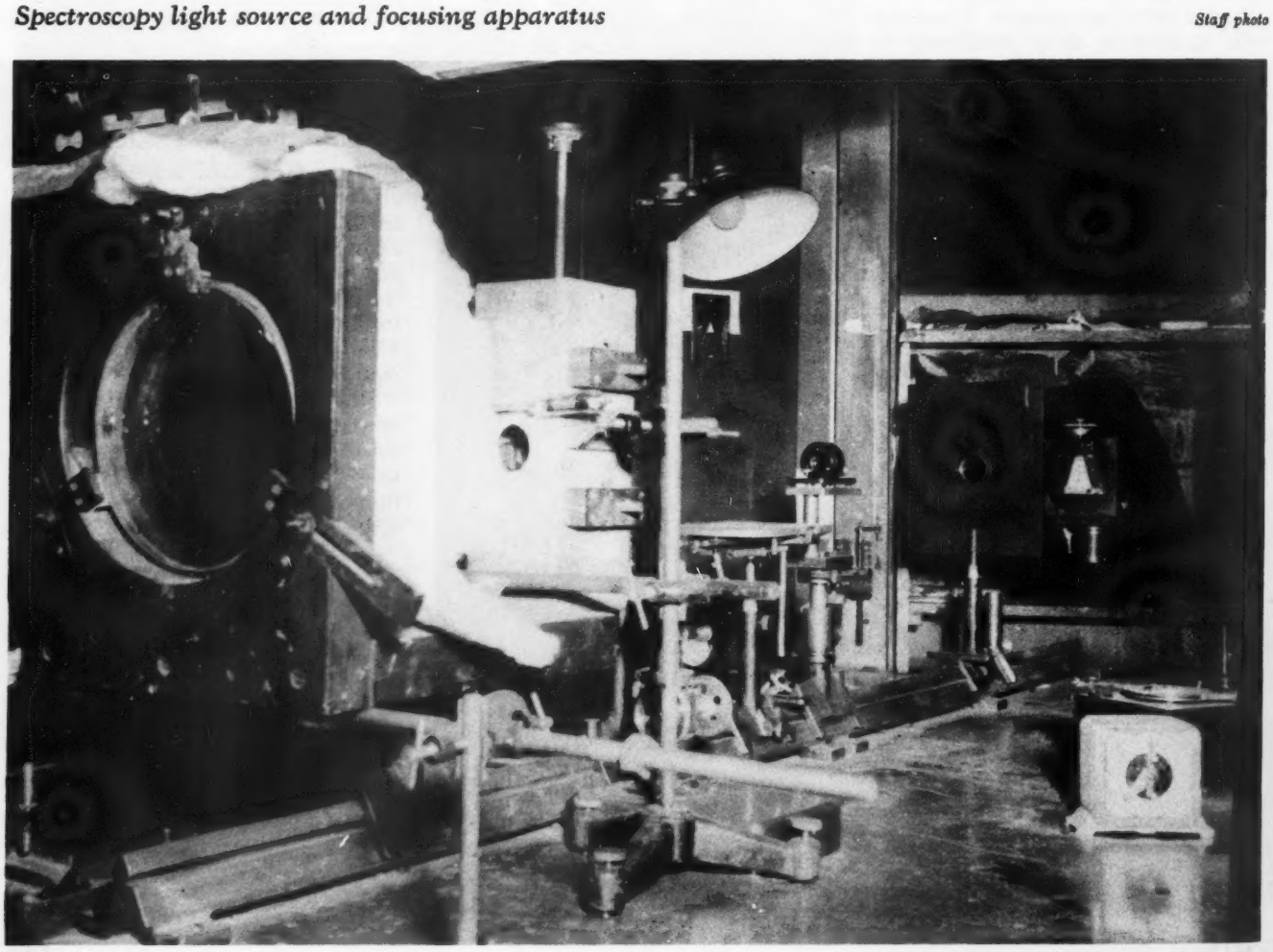
The whole building is isolated from the main buildings of Tech. It is insulated by its heavy walls and by layers of felt and cork. To insure against shocks through the ground the foundation is carefully built and certain rooms are literally floating. Shaking by the winds is avoided, since it is surrounded by the main buildings.

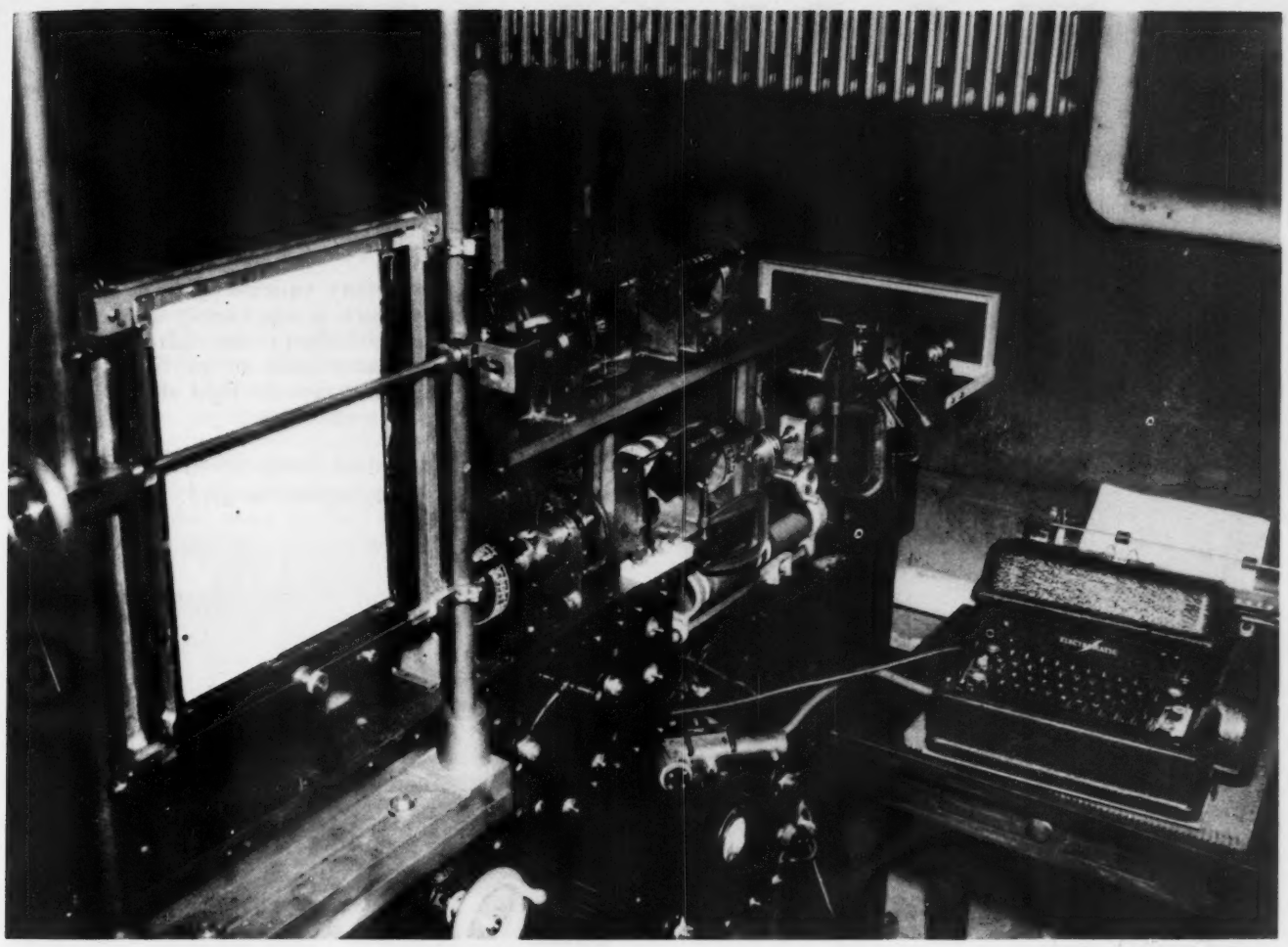
The main purpose at the present time is the determination of wavelengths of light, by which analyses can be made of the substance emitting the light. The lab is equipped to perform other purposes but these are not being utilized. The facilities are open to handle industrial as well as scientific investigations.

In order to determine the characteristics of a substance it is vaporized by means of a spark or arc. If a gas, it is made to give off light in a discharge tube. This light passes through an optical system and a slit. It is then broken up into a spectrum by a diffraction grating and reflected to photographic plates. The lines found give the necessary data.

The slit system is so arranged that the light can be projected from three different slits to different

Spectroscopy light source and focusing apparatus *Staff photo*





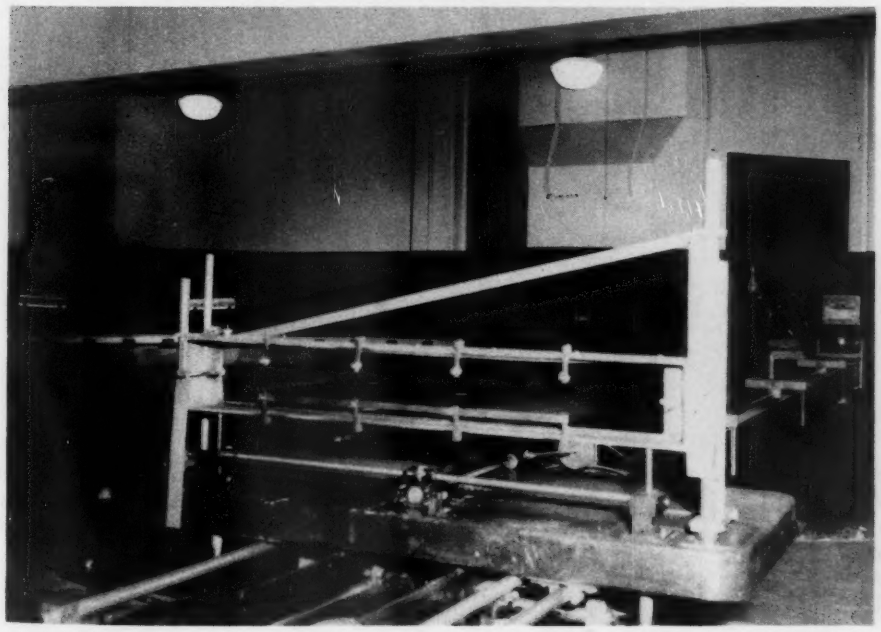
Spectroscopy lab computator *Staff photo*

gratings. Thus the same light can be reflected to various portions of the room.

There are two types of gratings: one with fifteen thousand lines per inch and another with thirty thousand lines per inch. They were constructed by Johns Hopkins, both by the same process. A pyrex blank has its surface ground to a spherical shape. Chromium and then aluminum are evaporated on its back. The rulings are made directly on the aluminum completing the grating.

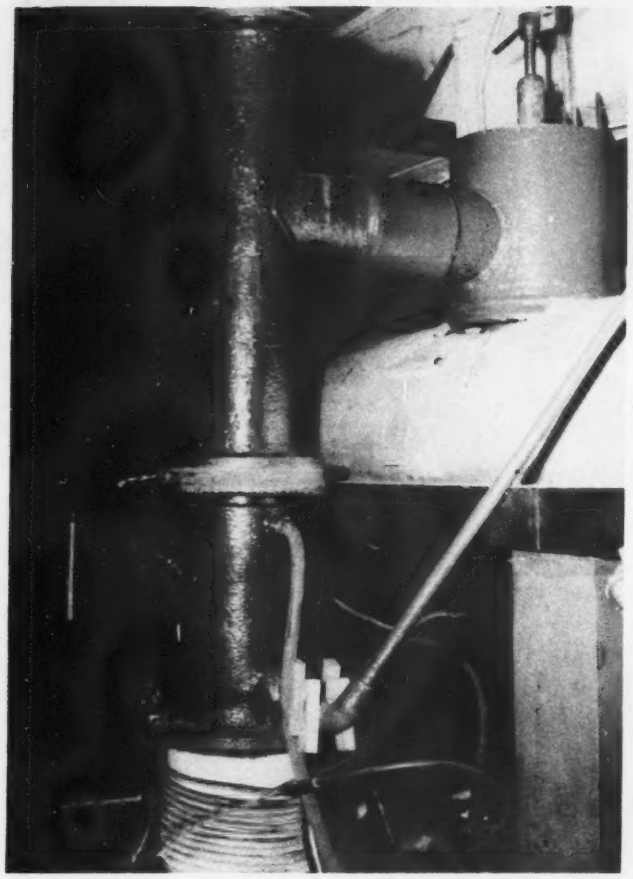
There are two projection rooms. One contains a twenty-one foot circle while there is a ten meter circle in the other. The photographic plates are placed on the rims of the circles which are arranged in such a way that light from the gratings is in focus at all parts along the rim. This allows the plates to be moved to any portion to catch the spectra. The ten-meter circle is complete but the twenty-one-foot is partially dismantled. In its place a Wadsworth stigmatic mounting is used. The main feature of this mounting is that it will take a parallel beam of light from any angle of incidence and focus the spectra normal to the diffraction grating. Thus on the mount the plate holders and grating are parallel.

Diffraction grating complete with slits and mounting *Staff photo*



Data obtained is processed into curves for the purpose of being interpreted by a computator. The machine used for this purpose was developed here at Tech during the war. It is just recently that information concerning it has been released.

Another piece of apparatus of



Staff photo

Special eight-foot vacuum pump used in spectographic work

interest is one that measures the transmission of a substance for wavelengths from two thousand to ten thousand Angströms. All this is done automatically with the instrument submitting a curve as its final result.

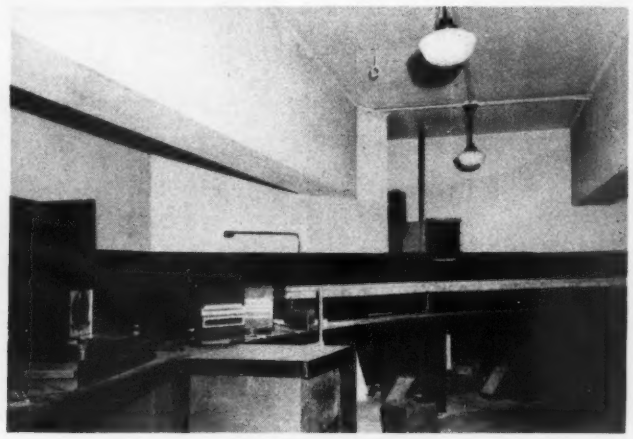
The light passing through the unknown sample creates a signal which goes through a photo multiplier and electronic system and is recorded. Light which has its intensity varied is passed through a standard. When the same signal is produced as that of the unknown a spark marks a point on graph paper and gives the transmission for a given wavelength. This process is repeated for the whole spectrum and forms a curve.

Dean Harrison has developed a method for analyzing the energy levels of spectrum lines. The apparatus consists of two parts. One finds lines of common intensity while the other associates these lines with definite parts of the spectrum.

The lab contains many vacuum spectrographs, the most impressive of which is one twenty-one feet long. It requires a vacuum diffusion pump eight feet high to evacuate it. These instruments are particularly valuable for working with ultraviolet light since this light is absorbed by air to some extent.

Diffraction grating and thirty-five-foot circle used to mount photographic targets

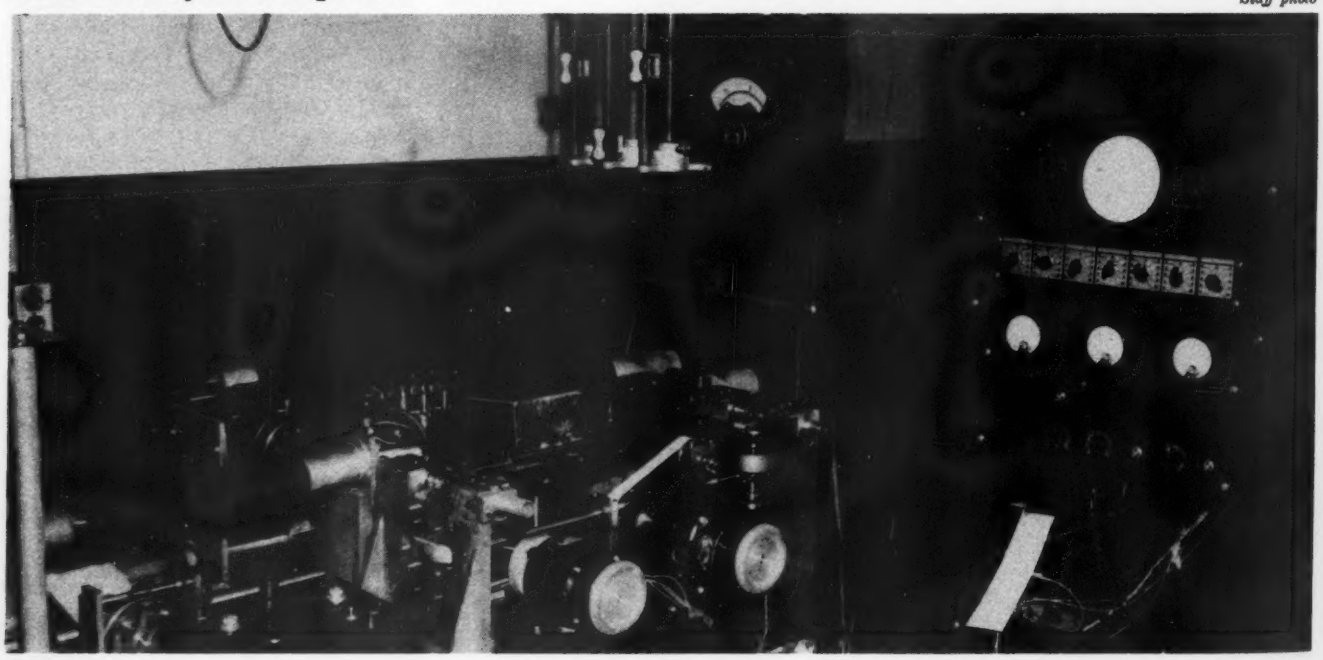
Staff photo



This completes the presentation of some of the main points of interest in regard to the lab. Lack of manpower and time have restricted the use and development of many instruments and fields of study in the present-day lab. But with the war over it is hoped that these difficulties may be disposed of and that the lab once again will be able to follow all the fields open to it.

Transmission factor computator

Staff photo



THIS IS M·I·T·

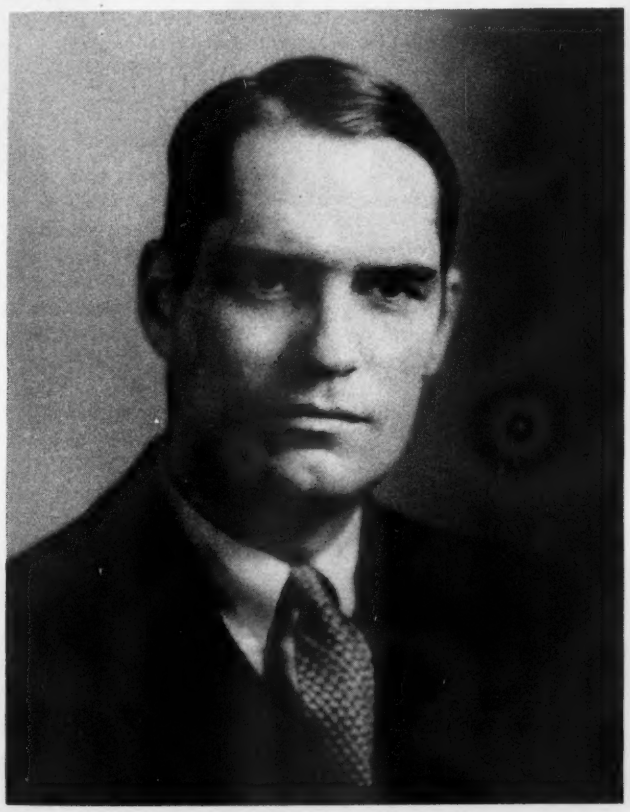
The Section of Graphics

By JOHN T. RULE, '21
Professor of Graphics

THE electric meter, the thermometer, the yardstick, the clock, and the balance are graphical devices. They measure physical phenomena by means of the position of a pointer on a graphical scale. The reading is recorded by the observer in the form of a number. The accuracy of this number is a compound of many variables, the two most obvious being the accuracy of the instrument and the accuracy with which the scale can be read.

Readings from the above devices supply the data for the great majority of engineering and scientific problems. Since such data are initially graphical in form and subject to graphical tolerances, they are not capable of yielding absolutely accurate numerical answers.

Professor Rule



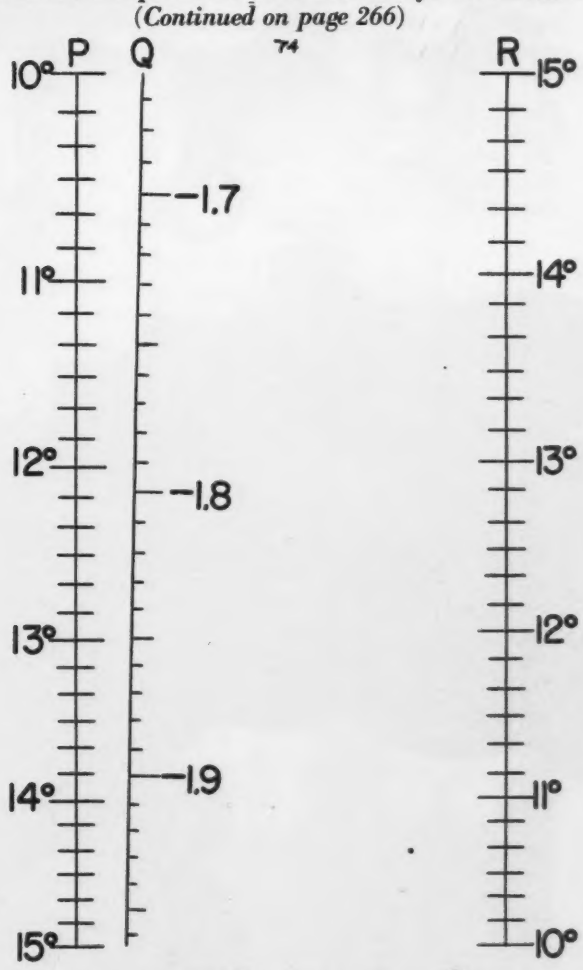
It follows that a graphical solution of an engineering problem based on such data will be as accurate as an algebraic solution, assuming the latter to include all functional mathematics, provided that the graphical solution is held within the accuracy of the original graphical data.

Furthermore, in certain classes of problems, the graphical and geometric approach often proves a more powerful tool than does the algebraic or functional approach. It is also frequently more revealing of hidden relationships and is thus apt to be more fruitful as a predictive tool. It is generally quicker and less given to accidental errors. There are also types of problems in which a combination of graphical and algebraic methods yields the best results.

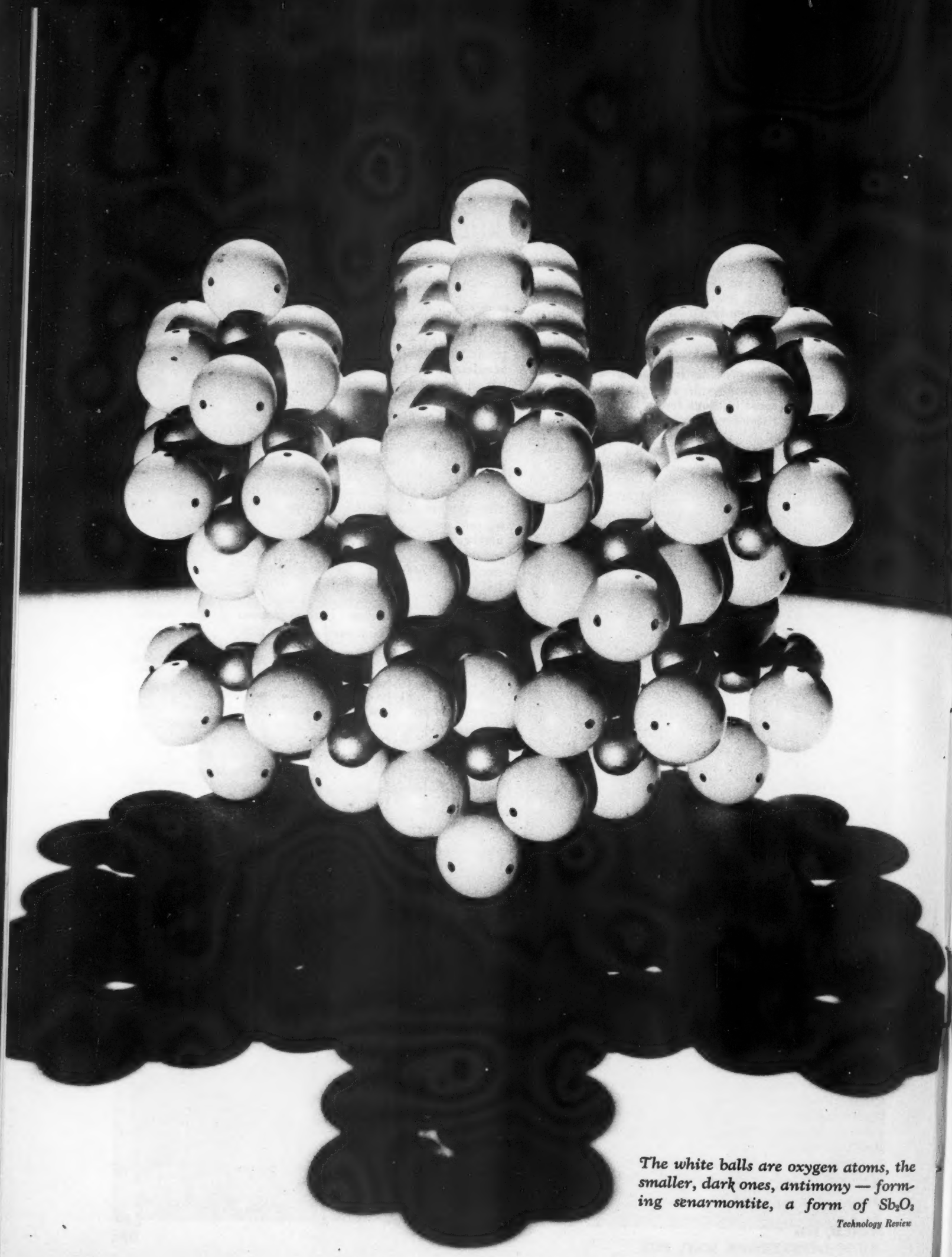
Ideally the competent engineer or scientist should be trained in the basic theories of both approaches so that he may intelligently choose the quickest and most illuminating. Certainly if he is not graphically competent, he is mathematically blind in one eye.

American mathematics has traditionally emphasized the algebraic approach. Consequently our student automatically tends to attack all engineering problems algebraically even though a geometric or graphical attack may be much simpler and more direct. He does not instinctively hunt for the graphical method nor does he feel sure of himself if he uses one. As a result he may either fail to solve a simple problem or find it much more complicated than is necessary. His mathe-

(*Continued on page 266*)



A typical nomograph — *Professor D. P. Adams*



The white balls are oxygen atoms, the smaller, dark ones, antimony — forming senarmontite, a form of Sb_2O_3

Technology Review

Crystallography

By NORTON BARON, 2-48

THE study of crystallography is the study of the forms, properties, and structures of crystals. To explain the nature of crystals, it would be well to go one step back and explain the process of crystallization — that is, the art of obtaining a substance in the form of crystals.

Through our chemical knowledge, we have found that the solubilities of substances generally increase with an increase in temperature. Consequently, upon cooling the mixture, the substance will precipitate out of solution in accordance with the temperature and rate of change of temperature. As a matter of fact, the slower the cooling process, the larger and more perfect will be the crystals formed. Occasionally crystallization does not take place as it should, even though the proper conditions exist. However, this obstacle may be overcome in a number of different ways. It may quite often be necessary to place within the solution a very small crystal of the substance desired. This small crystal may act as a nucleus for further crystallization. Sometimes, by shaking the solution or by adding another drop of solvent one can bring about crystallization.

Upon crystallization, there results a solid body that is bounded by plane surfaces intersecting in straight edges. The directions of these plane surfaces hold the key to the secret of the crystal's internal form.

The essential properties of crystalline matter may be divided into two classes: the general properties — such as density, specific heat, melting point, and chemical composition — and the directional properties — such as cohesion and elasticity, various optical, thermal, and electrical characteristics, as well as the external form.

There are three fundamental laws to which the crystal is wholly conformative.

1. *The Law of the Constancy of the Angle* merely states that the angles between the corresponding faces of all crystals of the same chemical substance are always the same and hence characteristic of the elements involved.

2. *The Law of Symmetry* refers to that symmetry shown to a point, a line or axis, or a plane. These elements of symmetry are spoken of as a center of symmetry, an axis of symmetry, and a plane of symmetry respectively. Crystals having a center of symmetry have their faces arranged in parallel pairs; the two parallel faces situated on opposite sides of the center. If, upon rotating a crystal about one of its axes a certain number of degrees, the orientation of its faces is the same as before the rotation, then the crystal possesses an axis of symmetry. If, upon passing a plane through a crystal, one half of the crystal is the mirror reflection of the other half in this plane, then the plane is one of symmetry.

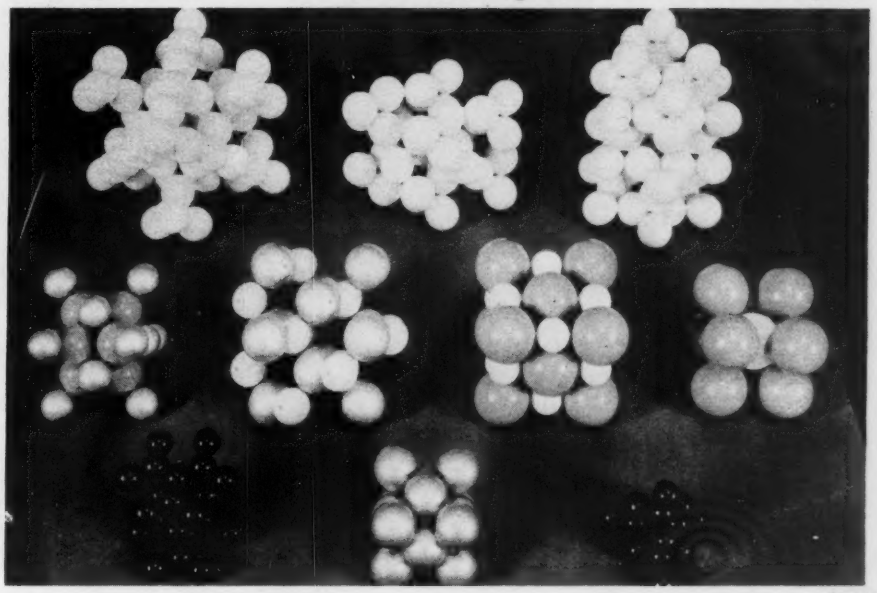
3. *The Law of Rational Intercepts* or *The Law of Rational Indices* as it is quite often called, brings forth an important relationship existing between the faces of a crystal. In order to fully understand this, consider axes of reference, OX, OY, OZ (any three edges formed by the intersection of three faces of a crystal). A fourth face on the crystal intersecting these three axes in points A, B, and C is taken as a parametral plane, and the lengths OA, OB, and OC are parameters of the crystal. Thus, any other face may be referred to these axes and parameters by the ratio of the intercepts $\frac{OA}{h}:\frac{OB}{k}:\frac{OC}{l}$, "$h$" referring to axis OX, "k" to OY, and "l" to OZ. The importance of this relationship existing between the faces of a crystal is that the indices h, k, and l are always rational whole numbers, rarely exceeding six and usually one, two, or three. Hence, the angular position of a face is thus completely fixed by its indices. Knowing the angles between the axial planes (planes in which axes of reference OX, OY, and OZ lie) and the parametral planes, all the angles of a crystal can be calculated when the indices are known.

As a result of the law of rational intercepts, there is now an arrangement of crystals in zones. All the faces which intercept in parallel edges are said to be in the same zone. A line drawn through the center of the crystal and parallel to these edges is called a zone-axis; and a plane perpendicular to this axis is called a zone-plane. Therefore, the direction of the line of intersection of any two planes (hkl) and $(h_1k_1l_1)$ is given by the zone indices (u, v, w), where u equals kl_1-lk_1, v equals lh_1-hl_1, and w equals hk_1-kh_1, this being obtained from the face indices by cross multiplication. Any other face $(h_2k_2l_2)$ lying in this zone must satisfy the equation

$$h_2u+k_2v+l_2w=0.$$

This important relationship between the indices of a face lying in a zone with the zone-indices is known as Weiss's Zone-Law, having first been proposed by C. S. Weiss.

As a result of the angular inclinations of the crystal-



Examples of various kinds of crystalline structure

lographic axes of reference and the lengths intercepted on these by the parametral plane, all crystals fall into one or other of six groups or systems. However, in each system there are several classes of crystals depending on their degree of symmetry. In fact, there are a total of thirty-two different classes of crystals distributed among the six groups.

The first system is known as the Cubic System in which the three crystallographic axes of reference are all at right angles to each other and are equal in length. In crystals of this system the angle between any two faces P and Q with indices hkl and pqr is given by the equation

$$\cos PQ = \frac{hp+kq+lr}{\sqrt{(h^2+k^2+l^2)(p^2+q^2+r^2)}}$$

The angles between faces with the same indices are thus the same in all substances which crystallize in the cubic system; in other systems the angles vary with the substance and are hence characteristic of it.

The second system is known as the Tetragonal System. The noted characteristic about this system is that the three crystallographic axes are all at right angles, but while two are equal in length and interchangeable, the third is of a different length. This unequal axis is spoken of as the principal or morphological axis of the crystal, and it is always placed in a vertical position.

The characteristic trait of the third or Orthorhombic System is the fact that the three crystallographic axes are all at right angles, but they are of different lengths and not interchangeable.

In the fourth or Monoclinic System, two of the angles between the crystallographic axes are right angles, but the third angle is oblique, and the axes are of unequal lengths.

In the fifth or Anorthic System none of the crystallographic axes are at right angles, and they are all of unequal lengths.

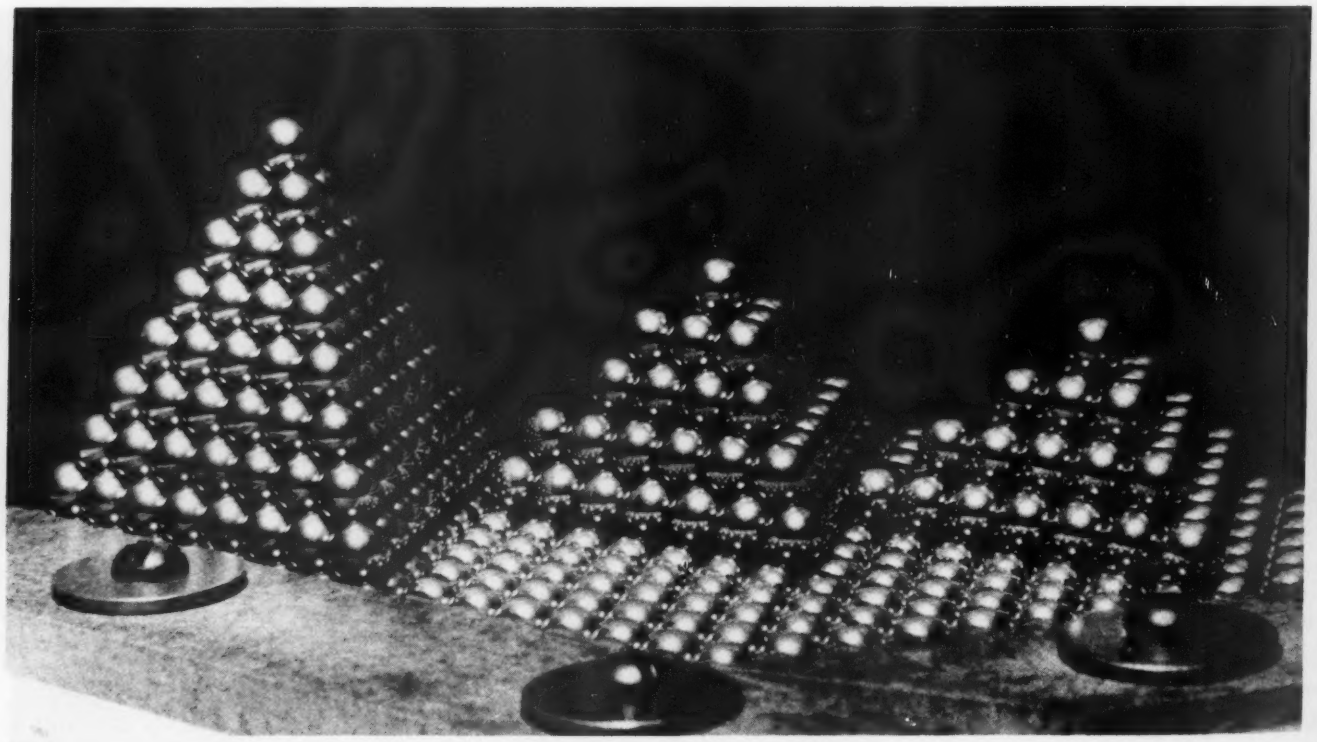
In the sixth or Hexagonal System, the crystals are characterized by the presence of a single axis of either triad or hexad symmetry. (A crystal possesses a triad axis of symmetry if upon rotating the crystal through 120 degrees the faces are reoriented. Similarly, a hexad axis of symmetry exists if the crystal reorients itself within an angle of rotation of 60 degrees.)

Occasionally, owing to changes in surrounding conditions, the crystal may continue its growth with a different external form. Indeed, there are frequently regular intergrowths of crystals of totally different substances. However, by far the most important kind of regular conjunction of crystals is that known as twinning. Here two crystals of the same kind have grown together in a certain symmetrical manner, such that one portion of the twin may be brought into the position of the other by reflection across a plane or by rotation about an axis. The plane of reflection is called the twin plane, and is parallel to one of the faces; the axis of rotation, called the twin axis, is parallel to one of the edges or perpendicular to one of the faces. Twinning may occur several times on the same plane or on other similar planes of the crystal, thus giving rise to triplets, quartets, and other complex groupings.

Only very rarely do crystals present a regular symmetrical appearance. This is due to the fact that the crystal is so placed within the liquid that there will be a more rapid crystallization on one side of the crystal than on the other side. Incipient crystals, whose development was arrested owing to unfavorable conditions of growth, are known as crystallites. They occur in imperfectly crystallized substances.

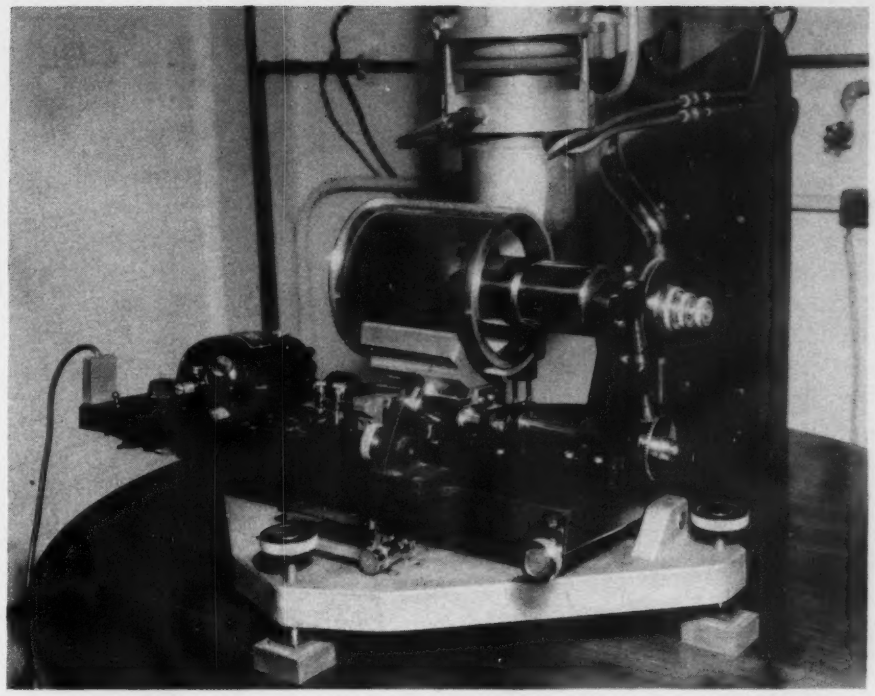
The idea of a regular underlying structure has always been at the back of scientific studies of crystals. It is suggested by their very appearance, and it becomes almost a necessity in order to explain the regularities of the laws governing the arrangements of the external faces and the physical properties of the crystals. Hauy,

The crystalline structure of various metals — represented by piles of quarter-inch steel balls arranged to fill space as densely as possible *Technology Review*



at about the beginning of the nineteenth century, brought forth the idea that crystals consist of a regular ordering of molecules in three dimensions. This regular ordering (space-lattice) of the molecules forms the basis for determining the different characteristics of the different crystals.

Although the geometrical framework for the complete description of the crystal structure had been worked out, there remained no way of applying it, since it was impossible to determine the nature of the space-lattice. However, a physicist by the name of Laue discovered, about 1912, that the lattices of crystals would defract X-rays in different directions. This was determined in an experiment which Laue conducted by placing a photographic plate behind a crystal through which he was passing a narrow beam of X-rays. The plate became covered with a regular pattern of dots. Thus the key to crystal structure was found.



Technology Review

Apparatus for precisely determining the repeat periods of the atoms in crystals. Distances can be measured with an accuracy of a ten-trillionth of an inch.

Upon this startling discovery by Laue, Sir William Bragg and his son, W. L. Bragg, determined the first crystal structures, those of rock salt and zinc-blende. Also, at the same time they developed a method of crystal structure analysis which was to be the basis for all further work. This is known as Bragg's Law and is stated in the equation $\sin\theta = n\gamma/2d$. γ is the wavelength of the X-ray, and θ is the grazing angle of incidence. The integer n is the so-called order of the reflection. Thus the same plane will reflect as angles $\theta_1, \theta_2, \ldots \theta_n$, where $\sin\theta_1 = \frac{\gamma}{2d}$, $\sin\theta_2 = \frac{2\gamma}{2d} \ldots \sin\theta_n = \frac{n\gamma}{2d}$ for the same wavelength. The higher the order or the smaller the spacing, the larger the angle of reflection. Hence we see that it is only necessary to measure θ, the angle at which X-rays of known wavelengths are reflected by a crystal, to know the spacing of its lattice planes.

In the Bragg ionization spectrometer, the X-rays pass through the two slits which limit them to a narrow beam, and then meet the crystal which is mounted to rotate about a vertical axis. The reflected beam is received in an ionization chamber, in which there is an absorbing gas such as methylene iodide producing ions which charge the electroscope. The crystal and chamber are then moved to record each reflection. Their angular position gives their glancing angle, while the ionization current is a measure of the intensity. The Bragg spectrometer undoubtedly provides the most thorough method of crystal structure analysis, but it is slow in action and suitable only for large crystals.

Another method of crystal structure analysis is known as the Rotation Method, which is originally credited to de Broglie. The X-rays are emitted from a tube, passed through a fine barrel aperture, and fall on the crystal, which is rotated uniformly on a spindle. As each crystal plane comes into a reflecting position, the reflected ray registers on a photographic plate producing a certain pattern. Each plane reflects four times per revolution, giving the photograph a symmetrical appearance. Thus, from the positions of the spot on the plate, the spaces or the indices of the plane can be calculated.

Another method of crystal structure analysis is known as the Powder Method and is originally due to Debye, Hull, and Sherrer. Here a crystalline powder is

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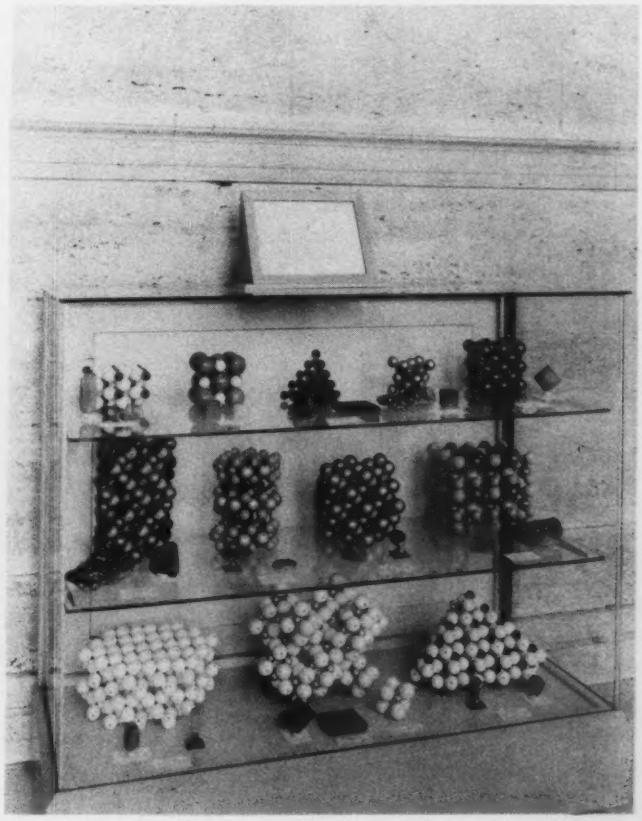


Part of M. I. T.'s extensive collection of models showing the atomic structure of crystals

Technology Review

A Wartime Miracle in Gas

Shortages of fuel, born of wartime needs, became especially acute along the Eastern Seaboard shortly after the commencement of hostilities. Due to the great demands of our armed services, nearly all the fuel at that time being transported to the Atlantic Coast was diverted to military channels. Clearly some means of transporting gasoline, oil, and natural gas economically, in quantity, was urgently required.

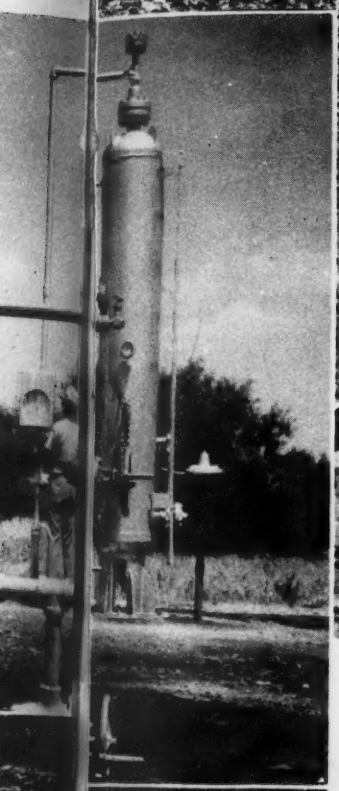
One of the solutions to this pressing problem was a pipe-line laid between Corpus Christi, Texas, and Cornwell, West Virginia. The engineers of this project were faced with four hundred miles of rock, six hundred miles of mountains and hills, and countless other natural and man-made obstacles. In their successful completion of this task may be seen one of the wonders of our age.

Above: Trenching equipment digging a short section of the 1265-mile ditch *Authenticated News Photo*

Right: The compressor station at Cornwell, West Virginia, from which gas is distributed to a six-state area *Authenticated News Photo*

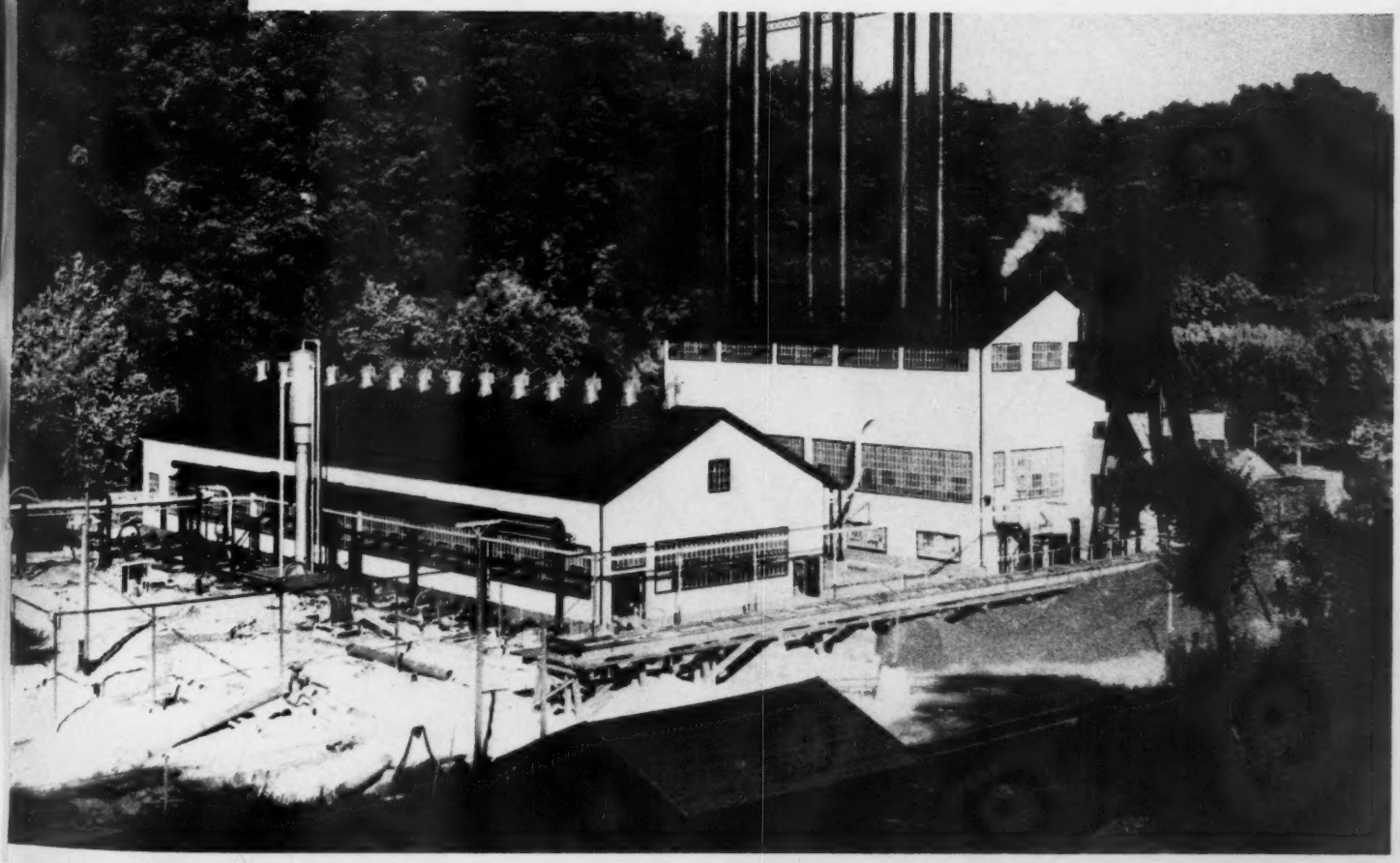
Authenticated News Photo

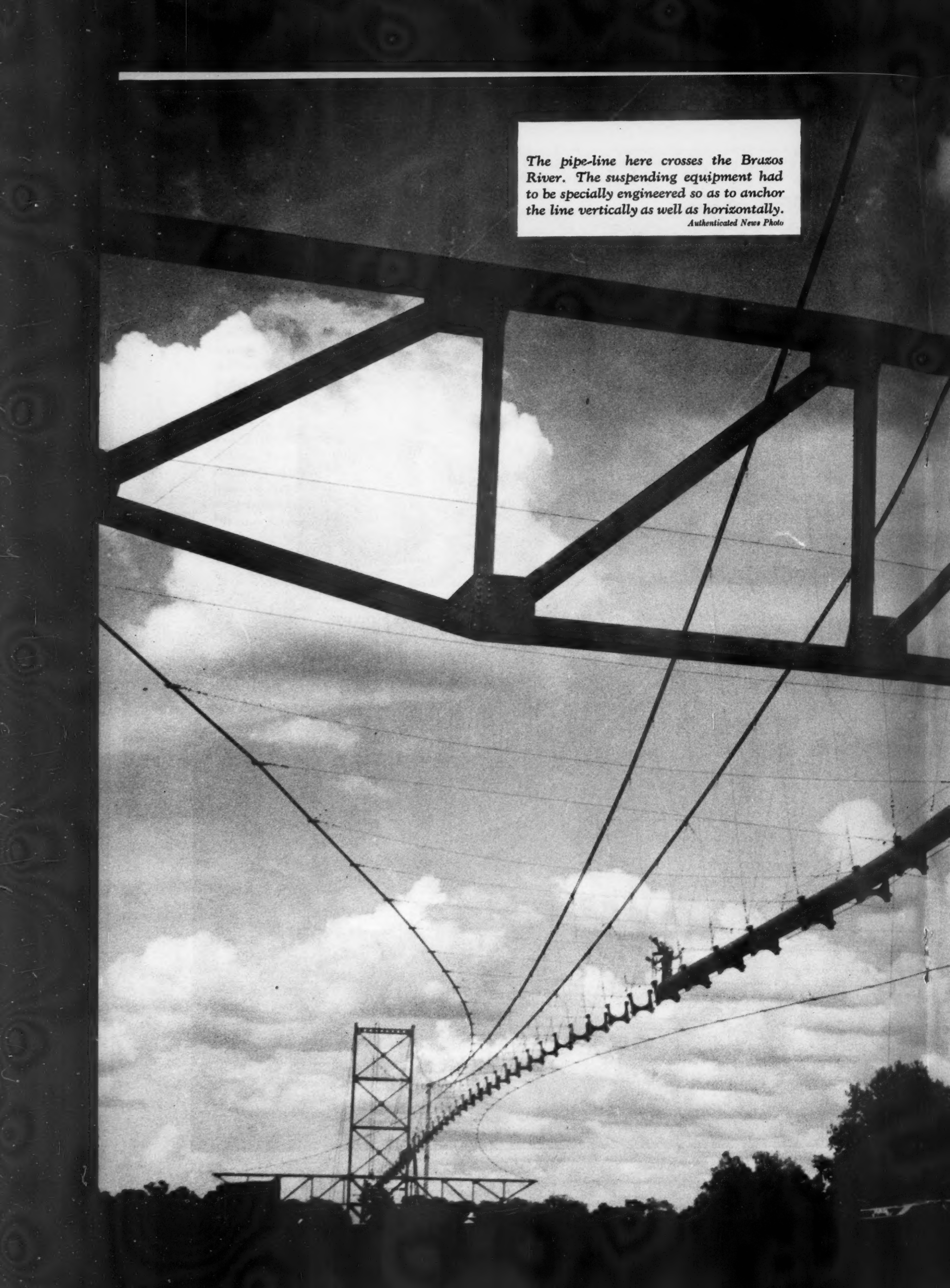
Above: Pipe-line tunnels through rock under one of the 274 highways on its route



Left: One of the natural gas wells which supply 200,000 cubic feet of gas daily

Authenticated News Photo





The pipe-line here crosses the Brazos River. The suspending equipment had to be specially engineered so as to anchor the line vertically as well as horizontally.

Authenticated News Photo

THE TECH ENGINEERING NEWS

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Can You Do It?

THE FIRST IN A SERIES OF MONTHLY BRAIN-BUSTERS

Quiz Master this month: PROF. DIRK J. STRUIK

In the posthumous papers of a slightly eccentric mathematician the following autobiographical notes were found.

"I could already read and write at the age of 10, so that I had little difficulty in entering the university at 31 years of age. I got my Ph.D. at 44, and one year later, as a man of 100, I married a beautiful young girl of 41, just out of college. The small difference in our ages made for common dreams and common interests. In four years we were a family of 10, father, mother and children, which was just the right size, though we had rather a hard time financially. During the first year of our marriage I had only 400 dollars a month, and though this doubled eventually to 1300 dollars, we were sorely pressed. I even had to give 1/10 of my salary to my mother, which left us with only 1120 dollars a month till she died at the age of 300."

Can you attach a sense to this rigmarole?

Answer next month

The Dragon's Den

Activities and the Veteran . . .

As we announced last month, because of the graduation of our General Manager, there would be a general shake-up in the staff. This issue represents the first concrete evidence of the labors of this new board.

And, as the Dragon frowns down upon the sacred precincts of his den, he notices a new trespasser — under the guise of an editorial writer. With a slight shudder he clutches more firmly to the volume of *T. E. N.* he roosts on and settles back to see what will develop.

The march of progress shall not stop, we promise. Since the last staff shake-up, much has been accomplished — the size of an individual issue is almost twice what it used to be, the staff has more than doubled, and three women have even been enticed into joining the efforts. That, however, is only a start. There is much yet to be done, and we now pledge to do our part in bringing the magazine to as close a state of perfection as is possible.

* * * *

At about the same time that this issue appears, a new class is entering Tech. Composed almost solely of veterans, this class typifies the general entering group throughout the nation, as G. I.'s under the "Bill of Rights" start to pick up the threads of their education where they were forced to drop them some years ago. And, entering along with these returned men, come some very difficult problems, both for the veteran and for the school.

To begin with, this influx of veterans means a general rise in the average age of the student body, with a corresponding rise in the intensity of study. This is so because these men seem to feel that they are back in school only for as long as it takes them to get their education and their degrees and that any extracurricular activity is but a distraction and a stumbling block on the road to graduation and a job. Furthermore, on the subject of these extra-curricular activities, the veteran seems to shy away from many of college doings because of the generally younger men in charge. They resent — and rightfully so — the probability that they will have to at least begin working under the authority of these younger men. Finally, the veterans tend to hang together, to form a closed society with themselves, as sort of a group of ex-comrades-in-arms. This latter feeling is all for the best and brings a strong, unusually progressive body to the campus. But the first two tendencies that we have noted are both unnecessary and harmful.

To begin with, a college education includes more than academic work. It is a generally rounded association, both with knowledge and with people in the presence of knowledge. But it is still more than that. It is a constructive lesson in human relationship, or how to get along with people in one easy lesson. It may be argued that the Army has provided much of this kind of education, but that argument answers itself, since the Army admittedly was an entirely different environment. While many of the human lessons can be gained under those circumstances, certain refinements are necessary to make the lessons applicable to civilian life. Certainly it is easier to learn these little, extra touches at college where everything is on a trial and error basis, than to have to be over-careful about making mistakes out on a job.

Probably some of the best opportunities for this informal association with other people come, not in the classroom, but on activities such as teams or publications, where all involved are trying for a common goal of achievement.

And it is probably here that the veteran need fear least being held under the authority of younger men. When an activity is properly run, authority and general importance vary directly with an individual's ability and, above all, good, old-fashioned drive. If the veteran sometimes finds himself under a younger and seemingly more inexperienced man, in the long run it should only be traced to ability. And, it should be remembered, things like that happen often in jobs later in life. It's all a question of effort put forth — and the proper direction of that effort.

All in all, what we are trying to say is this: the veteran need not shut himself up in his room and spend all his time studying, for much of college education can be missed that way. He should get out and join in some of the more rounded and varied parts of campus life. In that manner the inevitable barrier between him and his college breaks down, and harmony is established all around.

J. W. W.

The Pillory

Know all ye readers that the following persons have been convicted of being on the staff of that magazine known as The Tech Engineering News, and for that rank offense they are hereby sentenced to a one month stand in the public pillory.

Louis B. Wadel, 2-46

Dallas, Texas, is famous for many strange happenings. Among other things, it is the birthplace of Louis B. Wadel. After a notorious career at high school, Lou began looking for some asylum to fit his particular talents. Being an expert at buggering and the inventor of the universal null it was inevitable that he should select M. I. T. as the institution where he would continue his studies (?).

Somehow he managed to get good marks. This was due primarily to the fact that the profs could no longer tolerate his fabulous grin and his red hair and wanted to make doubly sure that he would not be with them the ensuing term. With the coming of Electrical Engineerings labs, Lou had many opportunities to use his cherished universal null — to the chagrin and confusion of the report correctors. By definition, the null is a number so chosen that it can be added to or subtracted from any number without altering the value of the original number. This also works in multiplication, division, differentiation, and integration. No matter what operation the null is carried through, it does nothing.

Looking around for something to do one day, Lou innocently walked into the *T.E.N.* office which miraculously happened to be open. Within a few weeks he had made his mark (an X) and felt that he could begin annoying people. That was a mistake, for it is a hard and fast rule around the *T.E.N.* office that annoying people are made make-up editor — which is just what happened.

Having been make-up editor for about four months — and never having made up an issue — he decided

(*Continued on page 274*)

F. Fausten Mark, 2-47

High above the petty clamor of the multitudes, proudly surveying his domain, lives the hawk of *T.E.N.* He is F. Fausten Mark, master physicist, herald of the great atomic age to come, discoverer of the hyper-super anti-emotionalizer and, last but not least, director of the notorious hooman-bean factory No. 2. Little do the struggling masses that toil to and fro beneath his window realize in whose hands their destiny lies. Only his closest associates understand that the future of a world is being decided in Wood 511 at this very moment.

Who is this mysterious man of power? What was the background of his mastery of energy and matter?

Scion of a noble family, F. Fausten came to Tech in July 1944. His eyes burned with the fanatic light of one who must become a physicist. Rapidly he mastered the trivialities of freshman and sophomore physics

and turned his piercing attention to the problems of the atom. Here, breathlessly followed by Professors Slater and Frank, he has succeeded in bringing atomic theory to its ultimate fruition with his shortly to be announced F-theory.

Having closed this glorious chapter in science, he is currently engaged in an investigation of the little-known field of coed hysteresis pre-examinitis. It was in the initial stages of this research that he devised his now-famous libido-frigido treatment. This has as its objective the transformation of libido into frigido and consists of a vicious onslaught by the patient against the walls and woodwork with a razor-sharp dirk. The therapeutic efficiency of this method has been a source of constant embarrassment to the dormitory manage-

(*Continued on page 274*)

NUMBER 2 OF A SERIES

Newsworthy Notes for Engineers

Resistors dressed in carbon

Early in the war, shortages of high resistance wire finer than a human hair, threatened the output of radar, electrical gun directors and high-frequency radio equipment.

Calling upon experience gained in telephone work, Bell Laboratories and Western Electric engineers broke this bottleneck with deposited carbon resistors.

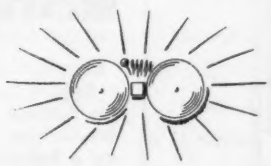
The base for one such resistor is a ceramic "pencil." This base slides through an automatic machine operated at high temperatures and receives a deposit of carbon film. Helical grooves are then cut in this film to provide a long, high-resistance path for the electric current.

Great savings resulted. For example: each 1-megohm deposited carbon resistor unit saves about one mile of wire, weighs about one-tenth as much and costs only one-twelfth as much as wire-wound units! In one war year, the saving was equivalent to more than 25,000 pounds of 46 gauge alloy wire.

Ringing the Bell on Reconversion!

One of the elements that makes the telephone ring is a pair of *ringer coils* —each coil 1½ inches long, tightly wound of 39 gauge copper wire. A horse hair is *thick* by comparison! So fine is this wire, that women with mechanical ability having fingers capable of fine needlework are selected to operate the complicated automatic machines which wind the coils, eight at a time, on one "stick."

Reconverting for production of ringer coils was one job for Western Electric production engineers. On the first Monday, exactly 80 coils—enough for only 40 telephones—were wound. On the fourth Monday, 8,232 coils were wound.



That's just one example of how production engineers have been ringing the bell on reconversion in making the 429 parts which go into the combined dial telephone set.

Prospecting for Mica in a Junk Heap

Until war put the clamps on shipping, mica from India held top place in the manufacture of capacitors used in radio circuits. As the shortage became acute, old methods of stamping out blanks by hand—which wasted a lot of mica—had to go.

Western Electric engineers attacked the problem of cutting down this wastage—devised a machine to hold the sheets of mica during punching.

This machine made possible the production of capacitor blanks from sheets of mica smaller than ever before usable—reduced scrap to a minimum. What's more, output soared—operators were less fatigued and worked more safely—inspectors found fewer imperfect blanks in each tray.

Manufacturing telephone and radio apparatus for the Bell System is Western Electric's primary job. It calls for engineers of many kinds—radio, electrical, mechanical, chemical, metallurgical. Many of the things they do —whether seemingly little or big—contribute greatly to the art of manufacture of communications equipment.

Western Electric

SOURCE OF SUPPLY FOR THE BELL SYSTEM

Watson Barracks

ARMY UNIVERSITY

(*Continued from page 242*)

students and staff to benefit in every way from the time spent in England. Stratford-on-Avon was only about fifty miles away, and during the summer while a repertory company was presenting Shakespearean plays at the new theatre there, a bus left for Stratford every evening. One or more busses also ran to Oxford every evening. Bus trips on Saturdays and Sundays, with local guides, could be taken to such places as Bath, Winchester, Eton, Windsor, Salisbury, and Sulgrave Manor, the ancestral home of George Washington. Two special leave trains, accommodating about four hundred men, ran to London after classes on Friday, returning on Sunday night, and during the summer months a similar train ran to Bournemouth, a seaside resort town on the coast near Southampton. No military formations (except reveille) were required of the students, and aside from the formality of requesting a pass for week-end leave, everyone was free outside of class hours to plan his time as he pleased.

Before the first term opened, most of the Army officers were extremely skeptical as to the success of the school. The men, they said, would look on their assignment merely as an eight-week vacation, and dire predictions were made that a civilian faculty would be unable to maintain discipline in classes. Nothing of the sort happened. Far from considering it a vacation, the overwhelming majority were eager to take every advantage of their opportunity to brush up on subjects in which they were rusty or to acquire additional credits. There were even complaints that no more than three courses could be taken, and that the time they were required to spend on athletics each day interfered with

(*Continued on page 276*)

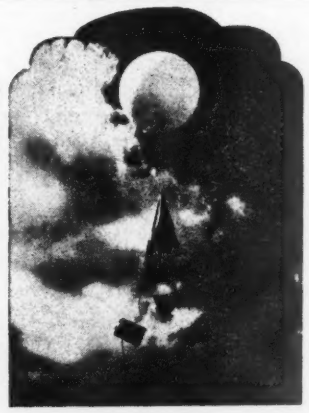
SINCE 1905

CONDUITS, SURFACE RACEWAYS
WIRES AND CABLES

National Electric
PRODUCTS CORPORATION
Pittsburgh, Pa.

Flight-tested to 100 Degrees Below Zero with

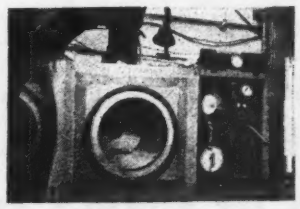
FRICK
Refrigeration



Reports on the temperature, humidity, and pressure of the air are radioed back to recording instruments on the earth by the Bendix-Friez Radiosonde, carried to heights of 16 miles or more by a balloon. These "weather" reports proved invaluable to the United Nations during the War: thousands of Radiosondes were sent aloft each month.

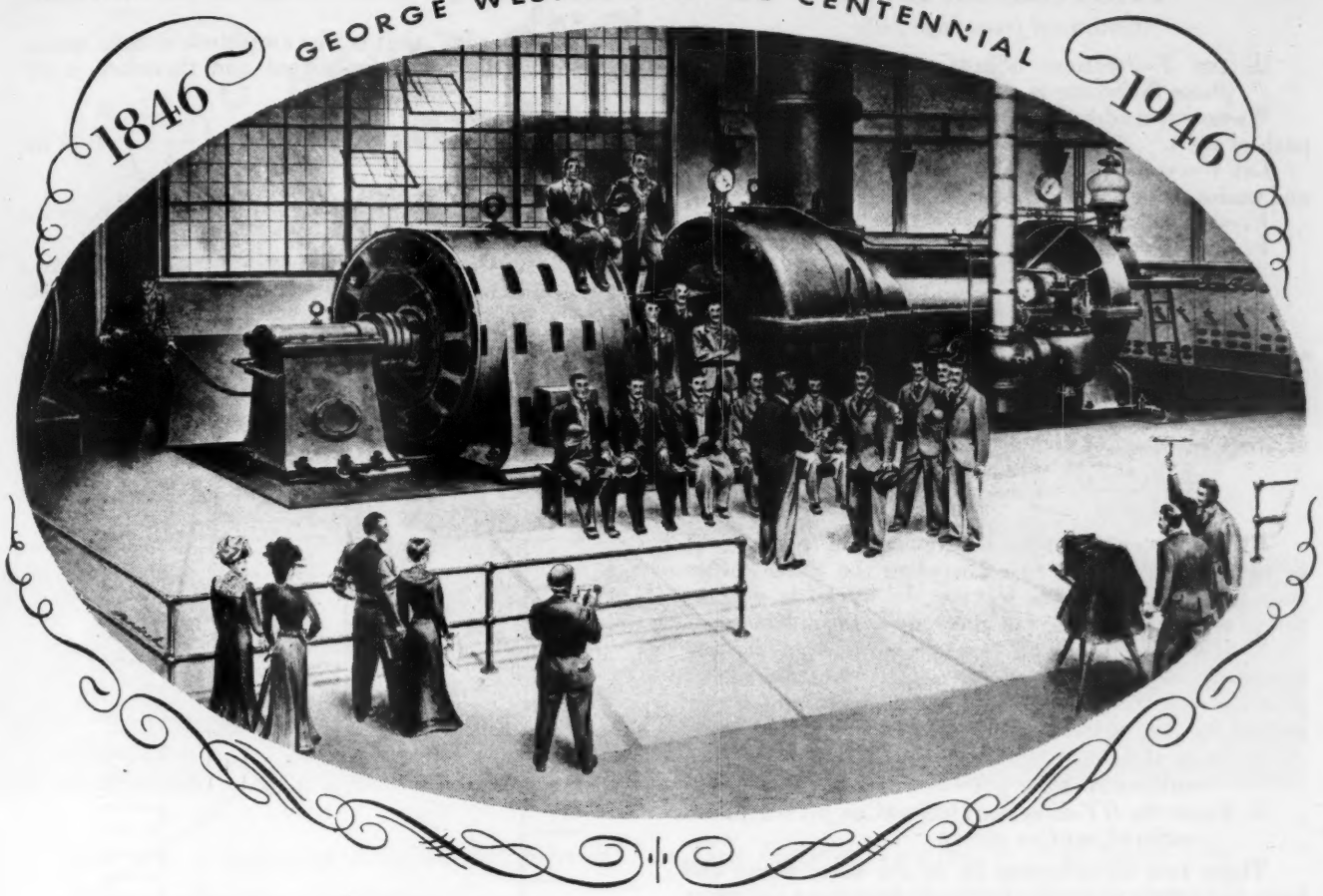
The Friez Instrument Division of Bendix Aviation Corp. calibrates Radiosondes in its plant at Towson, Md., with the test chamber shown below. This is cooled from + 104 to — 100 deg. F. in 75 minutes, the air pressure being simultaneously reduced to match flight conditions. Cooling is accurately controlled by a two-stage Frick refrigerating system using Freon-22.

The installation was designed and erected by the Paul J. Vincent Co., Frick Distributors at Baltimore.



For the solution of that particular refrigerating, ice-making or air conditioning problem of yours, get in touch with the nearest Frick Branch or Distributor.

FRICK CO
WAYNESBORO, PENNA. U.S.A.



WHIRLING POWER

EARLY in life, George Westinghouse dreamed of a new and better source of power that would make obsolete the ponderous *reciprocating* steam engine of his day.

Even as a boy he had wrestled with the problem—securing his first patent on an engine of the *rotary type* when only 19 years old.

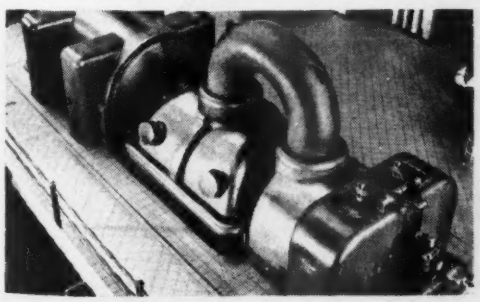
Years later, Westinghouse heard the exciting news about a *new type of rotary engine,* developed by Sir Charles Parsons in England. It was a steam turbine . . . using *jets of steam* to drive whirling blades.

Here was the answer to the problem that had fascinated Westinghouse since boyhood—and he promptly acquired the rights to manufacture the turbine in America.

The next few years were busy ones for George Westinghouse. With characteristic energy, he applied all his inventive genius in developing the still crude steam turbine into a *compact power source* for generating electricity.

Then, in 1900, Westinghouse installed a 2000-kilowatt steam turbine generator at Hartford, Connecticut—by far the largest then in existence.

It was the *first* practical central station turbine generator in America . . . a *new* application of whirling power that was to bring electricity to people all over the world.



Westinghouse
PLANTS IN 25 CITIES OFFICES EVERYWHERE

***TODAY** . . . America annually produces more than two billion kilowatt hours of electricity and more than three-fourths of the generating capacity in America is in steam turbine generators. Westinghouse manufactured a large share of these turbine generators—some developing more than 200,000 horsepower each. In 1946, more than a million horsepower of Westinghouse steam turbines will go into American power plants.*

Tune in: JOHN CHARLES THOMAS—*Sunday, 2:30 pm, EST, NBC* • TED MALONE—*Monday through Friday, 11:45 am, EST, American Network*

PHOTOELASTICITY

(*Continued from page 240*)

In the Y-direction: $a\text{Sin}\,a\text{Cos}\,p(t-t_2)$ where the phase difference is equal to $p(t_1-t_2)$

We now consider the thickness h of the model in the path of light.

Let V = velocity of light in the unstressed material, and under stressed conditions:

V_x = velocity of light in the X-direction

V_y = velocity of light in the Y-direction

$$\text{Then } t=\frac{h}{V_x} \text{ and } t=\frac{h}{V_y}$$

Therefore, $(t_1-t_2)=h\dfrac{(V_y-V_x)}{(V_xV_y)}$. But a very slight change in the velocity of light will yield a very great difference in miles per hour or feet per second. Therefore,

$$\frac{h(V_y-V_x)}{(V_xV_y)}\approx t_1-t_2\approx-\frac{h}{V^2}(V_x-V_y)$$

By experiment, $(\sigma_x-\sigma_y)$ is proportional to (V_x-V_y) is proportional to (t_1-t_2). Therefore the phase difference between the waves leaving the model is proportional to the difference between the principal stresses.

If MN is the plane of transmission of analyzer and is approximately 90° to the plane of vibration of the polarizer, then the following disturbances are transmitted by the analyzer:

1. From the OX-direction: $[a\text{Cos}\,a\text{Cos}\,p(t-t_1)]\text{Sin}\,a = a\text{Cos}\,a\text{Sin}\,a\text{Cos}\,p(t-t_1)$
2. From the OY-direction: $[a\text{Sin}\,a\text{Cos}\,p(t-t_2)]\text{Cos}\,a = a\text{Sin}\,a\text{Cos}\,a\text{Cos}\,p(t-t_2)$

These two disturbances lie in the same plane and have the same amplitude, but their directions are opposite, therefore, one is negative. We choose the upward direction as positive.

Then the resultant is

$a\text{Cos}\,a\text{Sin}\,a\text{Cos}\,p(t-t_1)-a\text{Sin}\,a\text{Cos}\,a\text{Cos}\,p(t-t_2)$

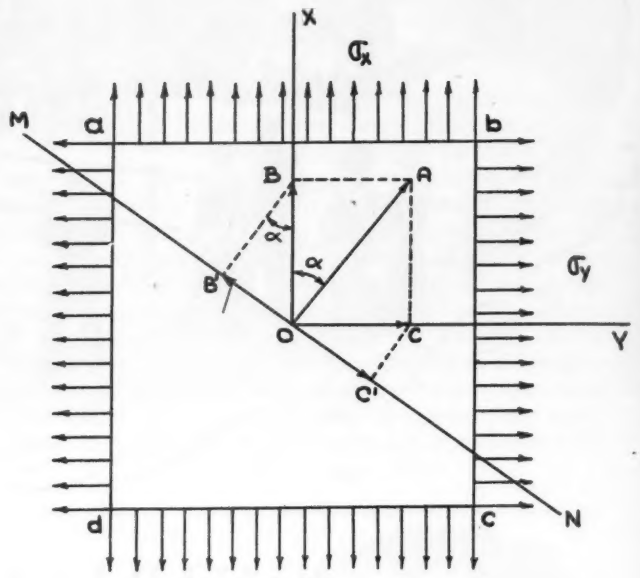
By algebraic manipulation we reduce this expression to $\left[a\text{Sin}\,2a\text{Sin}\,p\left(\frac{t_1-t_2}{2}\right)\right]\text{Sin}\,p\left(t-\frac{t_1+t_2}{2}\right)$ where the term in the brackets is the amplitude.

If $a=0$, no light passes through the polarizer, therefore, $a\neq 0$.

If $a=0°$ or 90°, that is, the amplitude is zero, meaning that no light is transmitted and therefore $a\neq 0°$ or 90°.

The amplitude will be zero when $p\left(\frac{t_1-t_2}{2}\right)=0$ or $n\pi$ where n is an integer. If $p\left(\frac{t_1-t_2}{2}\right)=0$, then $t_1=t_2$, meaning that the time is equal on the two principal stress planes and this is true only when $\sigma_x=\sigma_y$ or $\sigma_x-\sigma_y=0$.

Figure 2 — *Diagram by the Author*



Therefore if we have a line corresponding to the position $\sigma_x-\sigma_y=0$, we call it a line of zero interference. When $p\left(\frac{t_1-t_2}{2}\right)=1\pi$ the amplitude is zero, but $t_1-t_2\neq 0$ and $\sigma_x-\sigma_y\neq 0$. This is called a line of first order and so on.

The difference between the principal stresses equals a constant times the order of interference divided by the thickness of the model in the path of light, or

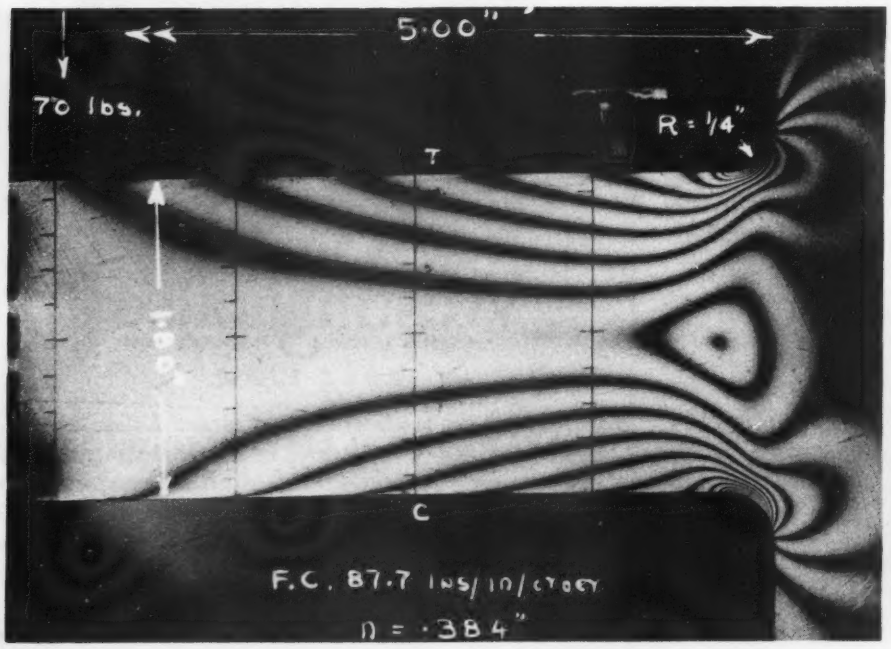
$$\sigma_x-\sigma_y=\frac{(C)(\text{orders})}{\text{thickness}}$$

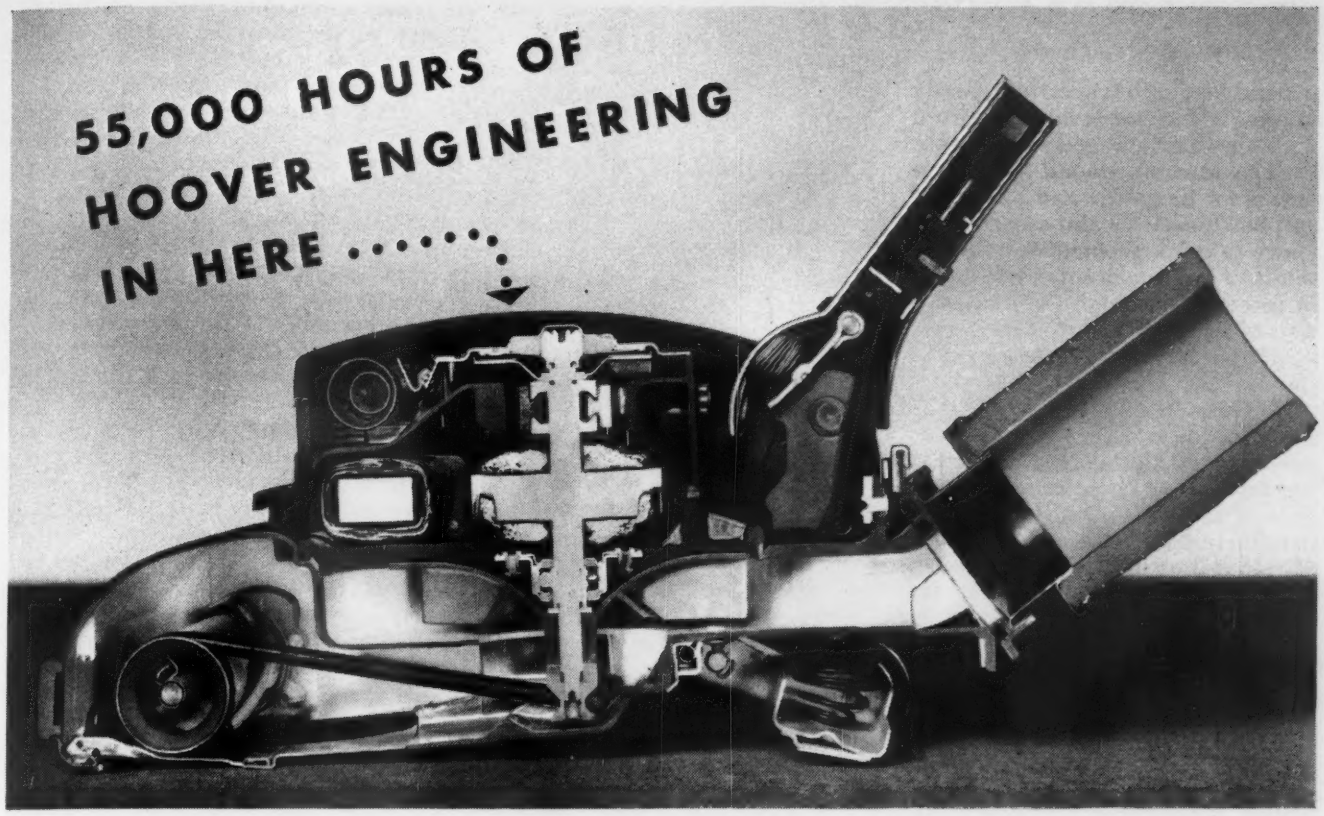
This constant is known as the fringe constant and varies for different photoelastic materials but is easily determined by experiment.

It is clear then that the difference in the principal stresses in a photoelastic model can be obtained by simply counting the orders of interference and knowing the fringe constant for the material and its thickness in the path of light. For example, in a cantilever beam with a load at the end, to calculate the stress at the point where the fringe of the fourth order intersects the edge we proceed as follows: The

(*Continued on page 272*)

A cantilever beam loaded at the end. Symbols refer to similar calculations in the text — *Professor William Murray*





There's a heap of engineering in a Hoover electric cleaner.

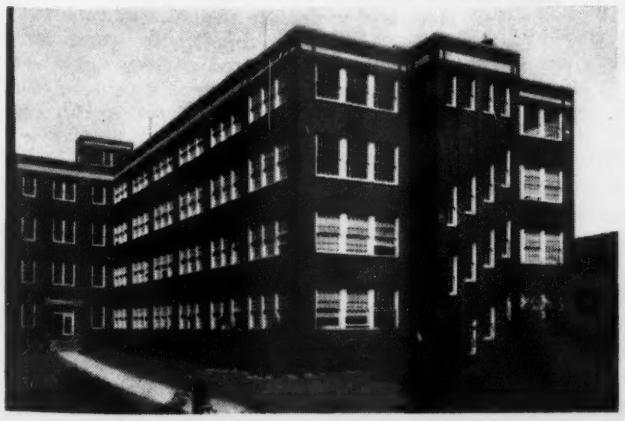
A typical model shown in cross section above required 55,000 hours of engineering research, study, and work to get it ready for production.

This is a fair average figure for new Hoover models.

The Hoover Company has been the world's largest manufacturer of home cleaners for nearly forty years. To maintain leadership, and be first with the latest and the best, Hoover requires the full-time service of an engineering staff of 130 . . . at least a third of them graduate engineers.

This modern four-story brick building, totaling 60,000 square feet of floor space and containing up-to-date laboratory equipment, is the Hoover Engineering Department.

The Hoover Cleaner is "born" in the development engineering division, where teamworking skilled designers, inventors and engineers plan tomorrow's electric cleaners.



The laboratory division studies and tests, rejects or recommends each component part of each new product "to be."

Mechanical engineers measure noise and vibration, design fan systems, study cleaning methods and solve power transmission problems in developing new designs.

Electrical engineers develop and test motors, wiring, switches, lamps, etc., designing the right power plant and accessories for a Hoover.

Product engineers solve manufacturing problems, set up standards, see that Hoover quality is maintained.

THE HOOVER COMPANY • *North Canton, Ohio*

SECTION OF GRAPHICS

(*Continued from page 249*)

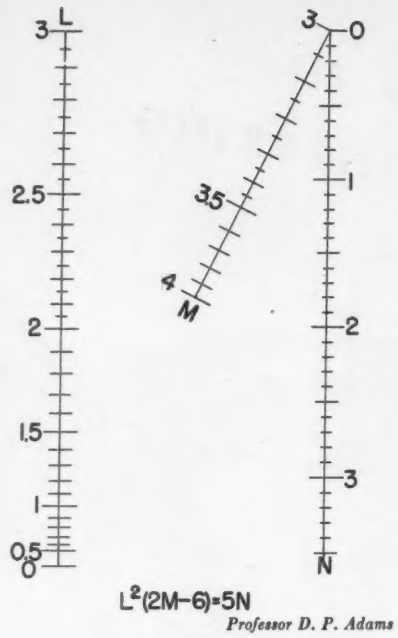
matical capabilities would be greatly improved if he normally thought in both algebraic and geometric terms.

The student should develop a feeling for the power and validity of graphical methods and a normal instinct to think geometrically and in terms of space concepts rather than in terms of formulas. The acquisition of the ability to do this is very nearly an unconscious process in that the student who conquers Descriptive Geometry is not necessarily aware of the fact that it has altered and enlarged the scope of his thinking processes. The common experience of finding the subject initially extremely difficult and finally quite simple is illustrative of this.

This general concept that the graphical approach is as valid as the algebraic approach is certainly the most important concept that the Section of Graphics can give the student.

Along with this, of course, the student must acquire some understanding of graphical accuracy. He must know how to obtain the most precise results and should develop some judgment concerning the accuracy necessary to solve any given problem within specific tolerances.

This is of the utmost importance for instance in the construction of nomographic charts, one of the most fascinating of all graphical subjects. The accuracy with which any equation can be solved in this form depends on the size of the chart, the ranges of the scales, and the accuracy of the draftsman. The figure shows a typical chart.



A second variety of nomograph

Professor D. P. Adams

In addition to the above broader aspects of graphical work there are many more specific functions which the Section of Graphics performs. A glance at the purposes of studying Engineering Drawing will illuminate these.

In the first place Engineering Drawing is the only course that the entering freshman takes which deals specifically with practical details. It is, in effect, his introduction to the necessary discipline of paying attention to minor methods, such as standards for screw threads and dimensions. These details frequently seem unimportant to the student. Narrowly interpreted the student is correct. The specific details are unimportant since they can be acquired at any time simply by looking in a textbook. However, the habit of paying attention to detail and of being professionally workmanlike, however tedious, is a habit which the engineer must acquire. He must learn to give the necessary attention to the enormous minutiae

(*Continued on page 276*)

LUFKIN "Peerless" Chrome Clad Steel Tapes

Rough, tough measuring work can't hurt the Lufkin "Peerless" Chrome Clad Steel Tape. Jet black markings are always easy to read. Sturdy steel line is covered with satin smooth chrome that resists rust and will not crack, chip, or peel. For free catalog write THE LUFKIN RULE CO., SAGINAW, MICH., New York City.

LUFKIN
FOR ACCURACY

CROSS SECTION OF AN ENGLISH CHANNEL CROSSER

Here is a weapon that beat the Wehrmacht, a cross section view of the submarine "cable" that piped oil from Great Britain to the Allied forces on the European mainland. Paid out from huge coils in the holds of ships, more than 20 flexible pipelines were laid under the English Channel.

As the picture indicates, this "cable" comprises a lead alloy tube, steel reinforcing tapes, steel wire armor and jute wrappings. It's actually a submarine cable except there's no core. Oil flows in the space normally occupied by the electrical conductors.

The Okonite-Callender Cable Company was one of four American wire and cable manufacturers who together turned out 140 nautical miles of this pipeline. Experience in working with others to solve special manufacturing problems is combined at Okonite with years of research and development work in electrical wire and cable improvement. The Okonite Company, Passaic, New Jersey.

OKONITE
4294 insulated wires and cables

The "TOM THUMB"

This was the first American locomotive. It was built in 1830 in a coachmaker's shop in Baltimore by Peter Cooper, an imaginative merchant. The flues of its boiler were old musket barrels, and its smokestack looked "like an aggravated putty-blower." On its first run — to Ellicott's Mills, with one car attached — it made as much as eighteen miles an hour going down hill. Some of the passengers took out their notebooks and jotted down sentences, to prove that it was possible to do so while traveling at such tremendous speed.

A century later came America's first streamlined train. Its journals were equipped with SKF Bearings. Pioneering for years in the railroad industry, SKF Bearings had already proven themselves by millions of miles of successful service under the most rugged conditions. Today SKF Bearings are an accepted standard for journals, for generators and for driving motors on the railroads of the nation. Since SKF makes so many types of anti-friction bearings, an SKF engineer can give you expert help in selecting

THE RIGHT BEARING FOR THE RIGHT PLACE

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BALL AND ROLLER
BEARINGS

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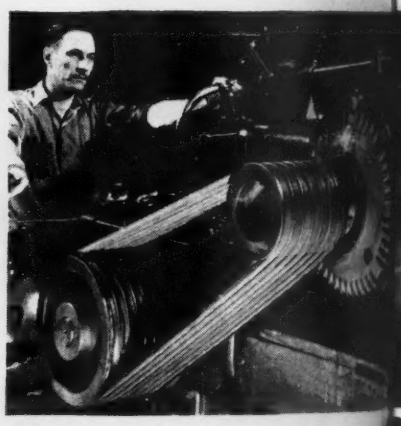
FROM THE RECORD OF ONE COMPANY:

Example after example of revolutionary new machinery and techniques that demonstrate the unlimited scope of Electric Power. How these Allis-Chalmers achievements point to great new peacetime applications in every field!

1 Early in war, A-C's work with el tric power helped to solve seri war shortages. For instance, light metal industries faced t problem: *How to boost output aluminum for fighting planes?*

5 To aid plants in figuring substation needs, A-C introduced a system of visual planning—*scale model layouts of power units and switchgear*—eliminated hours of paper work, complex tables, drawings!

6 New alternating-current welder, developed by A-C, gave shipbuilders and construction men important new production tool—used power more efficiently without converting to direct current.



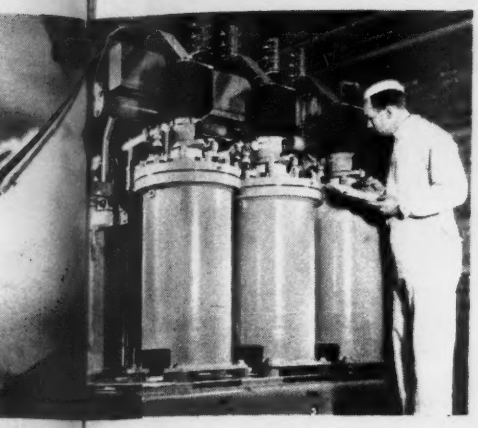
7 The multiple V-belt drive is an example of engineering leader Invented by Allis-Chalmers, these power-saving belts drive of all U. S. machines *regardless what they produce!*

TURN ON THE POWER FOR RECONVERSION!

Call on Allis-Chalmers' new War-Born Products and Techniqu for help with Technical Problems. At your command is the wid range of Industrial Knowledge and Equipment in the World.

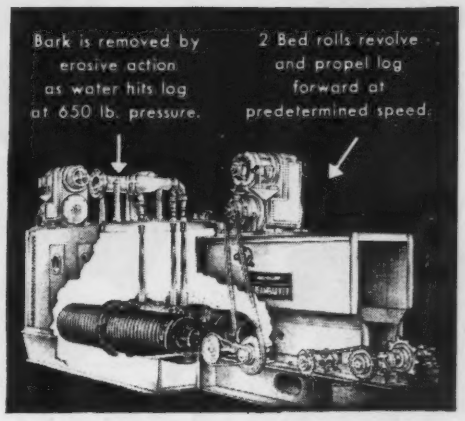
Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin

...ON POWER!



2 The answer was the Mercury Arc Rectifier — huge electronic device that reliably converts a-c to d-c current for electrolytic production of light metals. It was first introduced by Allis-Chalmers engineers!

3 Another electronic war development —*A-C's high-frequency Induction Heater*—greatly facilitates brazing, hardening and annealing of many small metal parts—saves time and work for metal-working industries!


Bark is removed by erosive action as water hits log at 650 lb. pressure.
2 Bed rolls revolve and propel log forward at predetermined speed.

4 To help relieve a paper shortage, A-C developed the Streambarker (unique machine using water pressure from power-operated pumps to strip bark from logs)—saved mills tons of precious wood pulp.

8 In steel plants, "Regulex" Control, developed by A-C, helped boost output of alloy steel for war use—by automatically controlling electric furnace temperature, making possible extra "heats," lower "melt" costs.

9 Today, on A-C drawing-boards are plans that put these *and many other* A-C war products to work for peace —will help lower unit costs, produce better clothing, food, cars, home needs *by putting more power to work.*

10 Coming to every field: more efficient methods and equipment for generating, distributing and using electric power thanks to A-C engineering! Call your nearby A-C office.

ALLIS-CHALMERS

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A-C

Tune in the BOSTON SYMPHONY Every Saturday, over the American Broadcasting Company Coast-to-Coast, 9:30 P. M., E. S. T.

WHO IS THE LOVELIEST LADY YOU KNOW?

YOUR SWEETHEART? Your sister? Is she someone you know well . . . or someone glimpsed fleetingly in a crowd? Is she blonde or brunette or titian? A movie star, perhaps?

Whoever she is, the chances are that a little black lump of coal has helped to make her beautiful!

For these days, many of her cosmetics contain derivatives from coal—in colorful dyes and delicate fragrances. Lipstick to harmonize with her coloring. Tinted face powder. Rouge. Eye-shadow. Nail polish.

Helping to create beauty is just one of the jobs coal does. Derivatives from coal also are helping to cure the sick, to grow better garden crops, to make plastics, paints, lacquers, to drive airplanes and stoke blast furnaces. In fact, you'd have to search long and hard to find a more versatile performer than a little lump of coal.

For a long time now, Koppers chemists have been studying coal, experimenting with it, making useful chemicals from it. And today, Koppers is producing, in commercial quantities, scores of chemicals for manufacturers to use in finished products of all kinds.

In addition to having a thorough knowledge of the chemistry of coal, Koppers also designs and builds coke ovens, treats wood with preservatives, manufactures piston rings, couplings, airplane propellers, roofing and paving materials, and engages in numerous other activities besides. That's why Koppers is known as "the industry that serves all industry". Koppers Company, Inc., Pittsburgh 19, Pa.

The industry that serves all industry . . . KOPPERS

Industry Relies on COLUMBIA for Essential Chemicals

Columbia alkalies and related chemical products are essentials in processes employed by many basic industries . . . industries which supply countless needs of modern living.

SODA ASH	CAUSTIC ASH
CAUSTIC SODA	PHOSFLAKE (*bottle washer*)
LIQUID CHLORINE	SODA BRIQUETTES (*iron desulphurizer*)
CALCIUM CHLORIDE	CALCENE T (*precipitated calcium carbonate*)
SODIUM BICARBONATE	SILENE EF (*hydrated calcium silicate*)
MODIFIED SODAS	PITTCHLOR (*calcium hypochlorite*)

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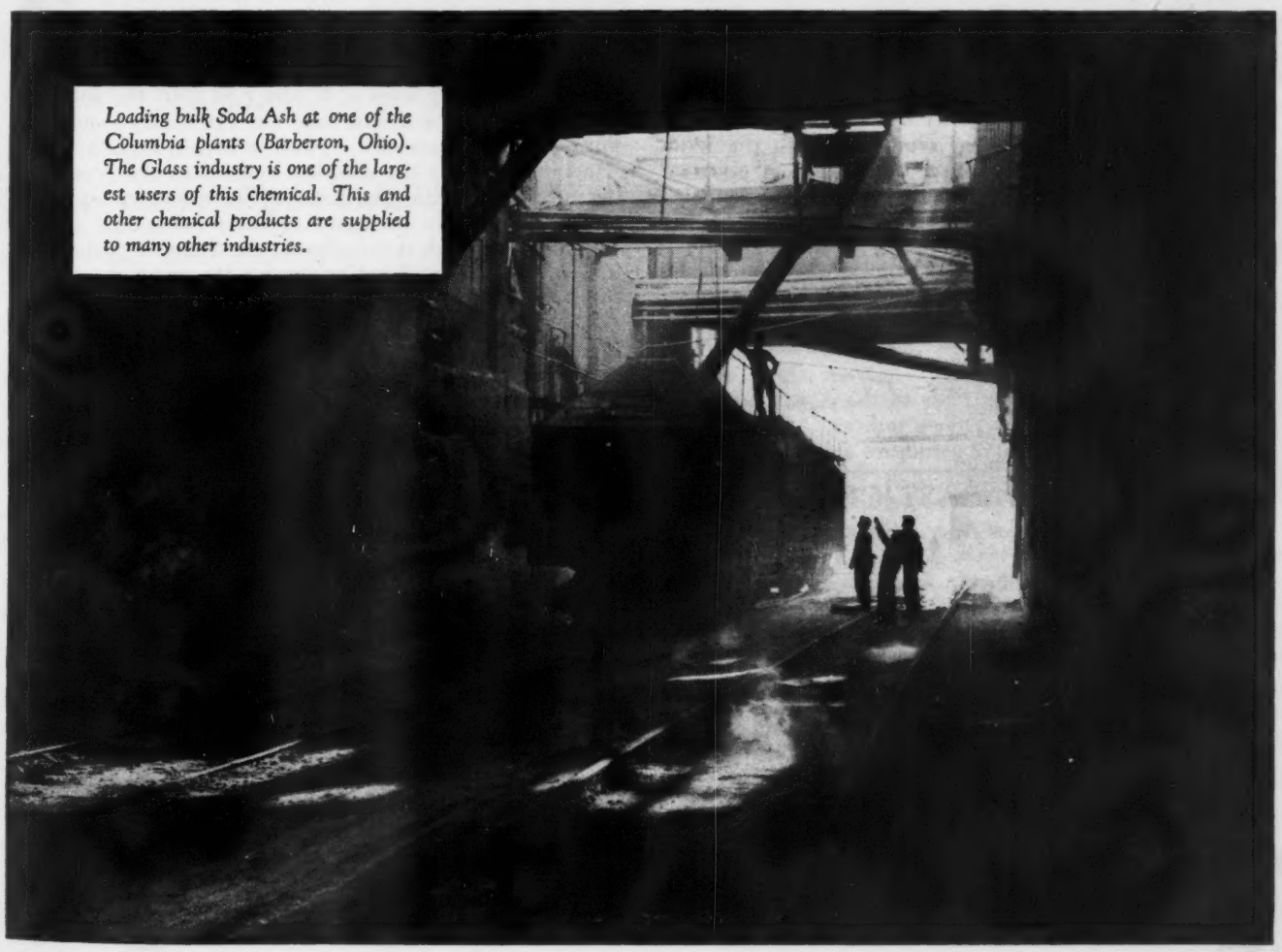
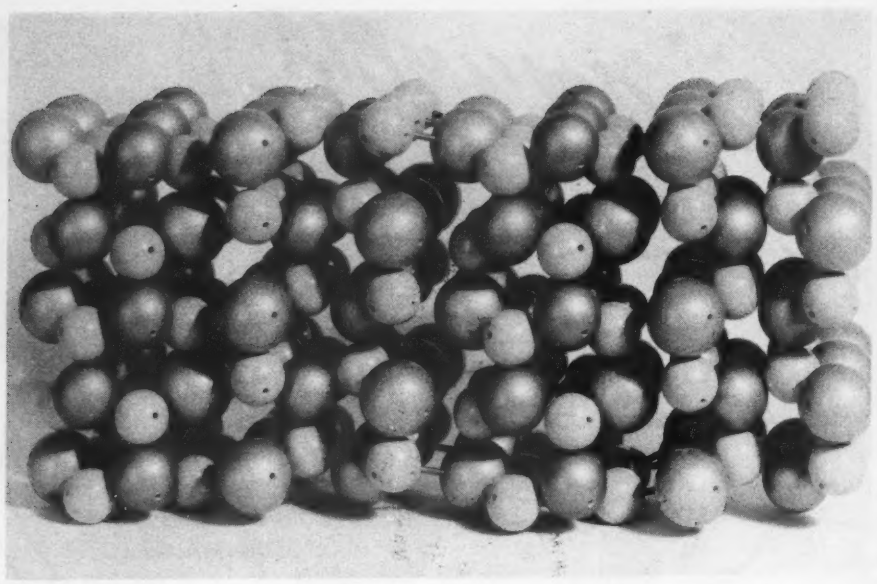


Loading bulk Soda Ash at one of the Columbia plants (Barberton, Ohio). The Glass industry is one of the largest users of this chemical. This and other chemical products are supplied to many other industries.



Models of atomic structures
Technology Review

CRYSTALLOGRAPHY

(*Continued from page 253*)

used instead of a single crystal, depending on the fact that among so many grains some will always be in the exact position to reflect. This method is very useful since it is the only possible method for substances which cannot be obtained as single crystals.

Still one more method of crystal structure analysis is known as the Laue Method. However, this depends on a principle different from the first three. Here the crystal is kept fixed and a beam of white X-rays (wavelengths ranging from between .25 to .5 Angstrom; Angstrom units equal 10^{-8} cm) is passed through it, usually parallel to a crystallographic axis. For a great number of planes there will always be some wavelength which is right for reflection and a spot is formed, the position of which depends only upon the angular position of the reflecting plane. Thus, although the Laue Method gives no information as to spacing, it gives an excellent picture of the crystal's symmetry and also of the relative intensities of a great number of the reflecting planes.

It is quite apparent that any one of these methods. except the last, could be used alone for crystal analysis, but it is much better to use all of them to amplify and to check results. Indeed, this is the way we arrive at experimental data for crystal analysis, the study of the spacings and the intensities of the X-ray reflection of a number of planes of known indices.

In the actual process of structure analysis, it is first necessary to determine the size of the unit cell (the segment of a crystal that contains all of its characteristic properties). This is done by determining the lengths of the three axes *a*, *b*, *c*. These are found with the aid of rotation photographs or from the spacings of the planes given by certain formulae. Next, in order to determine the number of molecules per cell, the density and the volume of the crystal must be known. Then the cell will contain Z molecules of molecular weight M, where $Z \times M \times 1.66 = \text{Density} \times \text{Volume}$.

The determination of the Lattice type is done by means of the halvings of planes of the type *hkl*. In simple lattices there are no inner regularities and all kinds of planes appear; whereas in centered lattices certain planes are interspaced identically so that they do not reflect in odd order and are said to be halved.

To determine the particular space group of a plane, it is first necessary to know the crystal class. This must be done by the methods of ordinary crystallography. Laue photographs are useful in detecting axes, but unfortunately X-ray methods cannot distinguish directly between crystals with or without a center of symmetry. Space groups are then found with the aid of certain tables which make use of the above information. Once the space group and the number of molecules per unit cell are known, the symmetry of the individual molecules follows. Furthermore, the conditions of symmetry fix the positions of the atoms within certain limits. For example, if we designate the coördinates of the atom, referred to axes *a*, *b*, and *c* as *uvw*, the so-called parameters of the atom, then the symmetry conditions may fix the values of *u*, *v*, and *w* within certain limits. However, in only the simplest cases does the symmetry fix all the atomic positions. This difficulty of fixing parameters leads to many crystals being left at this stage, but though it is indirect, the fixing of parameters by intensity considerations is far the most interesting part of crystal analysis. The method consists of assuming certain values for the parameters and calculating from this the theoretical intensities of reflection from a set of planes. These are compared with the observed intensities, and the process repeated by trial and error until the theoretical and observed intensities agree within the error of the experiment.

PHOTOELASTICITY

(*Continued from page 264*)

fringe constant is 87.7 lbs./in./order, and the thickness of the model in the path of light is 0.384 inches.

$$\text{Therefore, } \sigma_x - \sigma_y = \frac{(\text{F.C.})\ (0)}{h}$$

$$\text{Or } \sigma_x - \sigma_y = \frac{(87.7)(4)}{0.384} = 914 \text{ P.S.I.}$$

By careful study of scaled photoelastic models we are able to consider stress concentrations and design full-sized metal structures and machines accordingly. For instance, in the light of the illustrated examples we may conclude that it is quite advisable to reduce stress at boundaries by introducing fillets and rounds wherever possible.

The Photoelastic methods of stress analysis are seen to be of invaluable aid in the solution of stress problems where it is impossible or extremely difficult to determine the actual positions and magnitudes of the principal stresses. There are, to be sure, other methods of determining stresses, especially the sum of the principal stresses, which are beyond the scope of this treatise, but which may be studied in any of the numerous texts on Photoelasticity. It is hoped that this article has helped gain an insight into the Photoelastic method of stress analysis.

The writer is deeply grateful to Prof. William M. Murray of the Massachusetts Institute of Technology for his generous aid in the preparation of this article and for the included photographs.

RCA Laboratories provides another great achievement in television—the "mirror-backed" Kinescope, or picture tube.

New "searchlight brilliance" for home television!

Now, large screen television pictures are twice as bright—yes, *twice as bright* as ever before!

You can "count every eyelash" in the close-ups. You'll almost want to shake hands with the people on your television screen—so great is the illusion that they are actually in your living room.

This new sharpness and brilliance is achieved through the new RCA "mirror-backed" Kinescope, or picture tube, perfected at RCA Laboratories.

It has a metallic film—eight-millionths of an inch thick. This metallic film acts as a reflector, allowing electrons to pass through to the screen but preventing light rays from becoming lost through the back of the tube. Just as the reflector of a searchlight concentrates its beam—so does this metallic film reflector double the brilliance and clarity of detail in home television receivers.

Similar progress-making research at RCA Laboratories is being applied constantly to all RCA Victor products—assuring you that anything you buy bearing the RCA monogram is one of the finest instruments of its kind science has achieved.

• • •

Radio Corporation of America, RCA Building, Radio City, New York 20. Listen to The RCA Victor Show, Sundays, 4:30 P.M., Eastern Time, over the NBC Network.

RCA Victor home television receivers will be available in two types. One model will have a direct-viewing screen about 6 by 8 inches. The other type will be similar to the set shown above—with a screen about 15 by 20 inches. Both instruments are being readied for the public with all possible speed and should be available this year.

RCA **RADIO CORPORATION of AMERICA**

Briefing the News . . .

Radar Developments . . .

The War Department recently removed secrecy restrictions on two wartime Signal Corps developments in radar which made possible the long-range plotting of enemy mortar and artillery positions and the detection of moving troops and vehicles on enemy-held roads at night.

Maj.-Gen. Harry C. Ingles, Chief Signal Officer of the Army, explained that sensationally accurate spotting of enemy gun positions at ranges of more than five miles was accomplished through radar detection of artillery and mortar projectiles in flight.

General Ingles said a specially adapted Signal Corps radar was used to obtain accurate oscilloscope bearings on both the upward and downward paths of an enemy projectile, and the entire trajectory of the shell was plotted from these bearings and extended geometrically to indicate the exact location of the gun.

This radar had an accuracy of twenty yards in range and one-third of one degree in azimuth (direction), the Chief Signal Officer said. On this basis it could spot a hidden gun position five miles distant with an error of not more than sixty yards.

The radars used to detect enemy night traffic had the uncanny faculty of being able to track all moving objects in the area covered by the radar beam. These too were standard Signal Corps radars which had been especially adapted for this function.

This modification was based upon what physicists call the "Doppler effect." This effect may be compared to the periodic bouncing of rubber balls. If a man throws rubber balls at a stationary wall at one-second intervals, the balls bounce back to him once a second. If the wall is not stationary, however, but moves toward the man, the balls return to him more often than once a second. If the wall moves away from him, the balls return less often. The same phenomenon is illustrated in the change in frequency of a locomotive whistle, which sounds higher in pitch when a train is speeding toward a listener and lower when it is speeding away.

On the basis of the Doppler effect, Signal Corps scientists knew that radar echoes would be reflected back at a different frequency from a moving object than from a stationary object. They modified their radars, therefore, to filter out echoes from stationary objects and present only data from moving objects.

Combat troops found this use of radar particularly valuable for night harassing fire of enemy supply routes. The accurate location of targets by radar resulted in a substantial saving of ammunition during the Battle of the Bulge, when ammunition supplies were critically short, and German prisoners reported that on several occasions the enemy had to abandon the use of his main supply routes.

Vehicular targets were detected by radar at ranges up to sixteen miles, although ten miles was the average maximum range. Individual troops were detected at ranges up to three miles, and the radar technicians became so proficient they could estimate the number of enemy soldiers in a group and the type and speed of enemy vehicles by analysis of their oscilloscope data.

Some astonishing results were obtained during the French and German campaigns. On one occasion radar data was used to inform an American patrol of the presence of a German patrol about two hundred yards to their right, with the result that the enemy patrol was ambushed.

On another occasion, the radar picked up three self-propelled guns moving toward our lines. A battalion concentration dispersed them. Again, a convoy of some forty vehicles was picked up and artillery fire was

(*Continued on page 278*)

The Pillory

(*Continued from page 260*)

Louis B. Wadel, 2-46

that it was about time that he did something decent for the magazine. His resignation was refused, however, and he was forced to make up an issue. That was too much.

When spring came along, Lou was one of the few men to be left after graduation had stolen most of the staff. As a horrible joke, the retiring managing board appointed Lou editor-in-chief. But Kismet was to intervene further and the regular general manager was sent to Great Lakes. This was a terrible blow, but Lou bravely volunteered to fill the gap. So it was that last fall found the infamous Wadel at the head of *T. E. N.*

Then things began to happen. Before anyone knew it the magazine began to sparkle a little. This new lustre could never be traced back directly to Lou, for the only thing he seemed to be doing was worrying. But somehow things kept moving.

So, with his recent graduation and election to Tau Beta Pi, Lou climaxed his career at Tech. We here at *T. E. N.*, in spite of the many insults we've hurled at his red head, have grown to respect and like this peculiar soul who never did any visible work but who managed to start the magazine down the long road to recovery.

F. Fausten Mark, 2-47

ment which has found it necessary to reline Fausten's room with stellite on four different occasions.

Not the least factor in the phenomenal success of the inscrutable Mark has been his devotion to order. From the entropy of a system at absolute zero to the arrangement of fly-tracks on his window panes no event associated with him can escape the influence of his meticulosity. Not even his porter dares draw breath within the sacred environs of his room for fear of disarranging the Brownian patterns of the air-molecules. The stern Fausten daily makes his own bed with a precision which no mortal hand could master.

As publications editor and now advertising manager of *T. E. N.* Fausten has brought to the magazine his amazing efficiency and knowledge. Former ad managers gasp with amazement at the order and neatness maintained in the present department. The entire publication reflects to a lesser degree the cleansing influence of this magnificent brain.

And so, as the whole world looks to this dynamic leader for its future, we bid him a fond farewell — for in all probability he is at present working out some advanced theory having to do with the elimination of personnel write-ups in magazines!

Argon

FROM THE AIR YOU BREATHE

. . . helps bring the world into your home

When you relax before your television set to watch headlines in the making, to enjoy a Broadway hit, a world-famed symphony or a great sporting event, the rare gas, Argon, contributes to your pleasure. This inert element—comprising less than 1% of the air you breathe—makes possible the trigger tube of the oscillograph used at the broadcasting end to assure high quality and fidelity in the reproduction of the image that appears on your viewing screen.

Argon is one of the industrial gases produced in Air Reduction's nationwide chain of plants and is also used in the manufacture of rectifier, transmitter and various other types of electronic tubes.

Other Airco gases include oxygen and acetylene for gas welding and cutting—carbon dioxide for preserving food and extinguishing fires — anaesthetic and therapeutic gases for medical, surgical and dental uses. In order that industry and science may realize the fullest benefits from the gases it produces, Airco also manufactures a complete line of apparatus and equipment for their use.

Write Dept. CP for your copy of the free 56-page book "A Quarter Century of Progress", describing the operations of Air Reduction and its subsidiaries.

• *The Operating subsidiaries of Air Reduction Company, Inc., are:*
AIR REDUCTION SALES COMPANY — MAGNOLIA AIRCO GAS PRODUCTS CO., Industrial Gases, Welding and Cutting Equipment • NATIONAL CARBIDE CORPORATION, Calcium Carbide • PURE CARBONIC, INCORPORATED, Carbonic Gas and "Dry-Ice" • THE OHIO CHEMICAL & MFG. CO., Medical Gases—Anesthesia Apparatus — Hospital Equipment • WILSON WELDER & METALS CO., INC., Arc Welding Equipment • AIRCO EXPORT CORPORATION, International Sales Representative of these Companies.

AIRCO

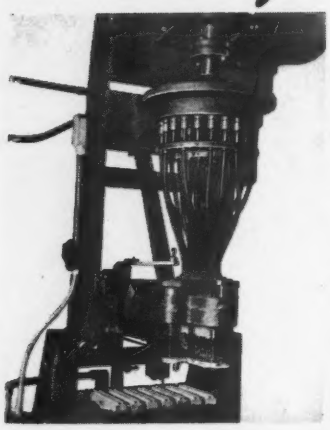
AIR REDUCTION

60 East 42nd Street, New York 17, N. Y.

S.S.WHITE FLEXIBLE SHAFTS

"Metal Muscles" for Power and Control

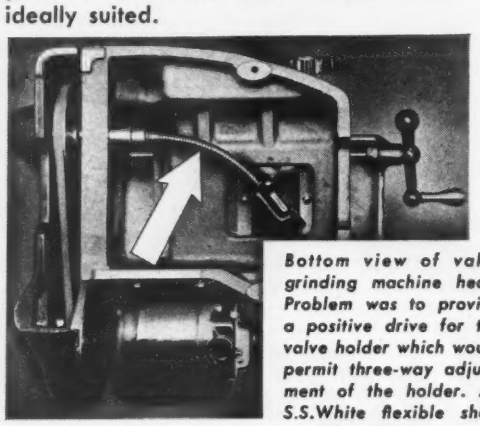
—the answer to many design problems . .



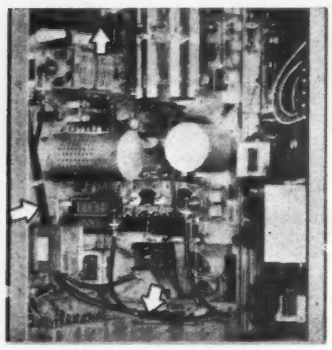
S.S.White flexible shafts as spindles in this machine, solved the problem of drilling up to 38 holes simultaneously in many different hole arrangements.

Problems involving the transmission of rotational power come up all the time in engineering design. And to many of them the simplest answer is an S.S.White flexible shaft —a single mechanical element that will carry rotational power between practically any two points, regardless of turns, obstacles and distance. Likewise, you will find S.S.White flexible shafts the answer to hundreds of mechanical remote control problems.

A few examples are shown of the kind of jobs for which S.S.White flexible shafts are ideally suited.



Bottom view of valve grinding machine head. Problem was to provide a positive drive for the valve holder which would permit three-way adjustment of the holder. An S.S.White flexible shaft was the simple answer.

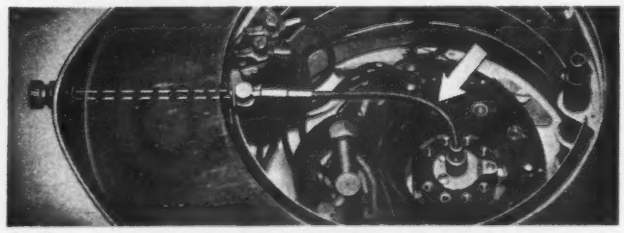


View inside a radio broadcast transmitter shows how S.S.White flexible shafts providea centralized control while allowing tuning elements to be mounted in the most favorable circuit and wiring positions.

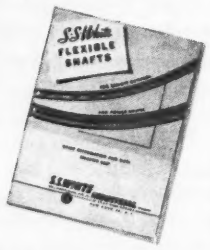
The simplicity and ready adaptability of S.S.White flexible shafts for a wide range of power drive and remote control requirements, explain their extensive and constantly increasing use—and are good reasons why design engineers should be familiar with the range and scope of these "metal muscles" for power and control.

WRITE FOR BULLETIN 4501

It gives the basic facts and technical data about flexible shafts and their use. A copy is yours for the asking. Please mention your college when you write.



In this unit (cover removed) the problem was to provide a means for operating a rotary switch from a convenient outside point. As can be seen, an S.S.White flexible shaft neatly does the trick.



S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. C, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

SECTION OF GRAPHICS

(*Continued from page 266*)

of engineering. More broadly he must acquire the disciplines necessary to translate his thinking into practical forms which are communicable without misunderstanding. His first contact with this aspect of engineering is in Engineering Drawing. He is, of course, at the same time accomplishing the obvious task of learning to draw.

As has been the case with most scientific fields, the war proved a tremendous force pressing toward developing new processes and ideas. Industry became acutely conscious of the extreme importance of drafting. The necessity for using unskilled workmen unfamiliar with engineering drawings vividly demonstrated the necessity for easily readable illustrative drawings.

As a result pictorial methods of representation were developed to the point where the entire field of drawing is practically undergoing a revolution. There is a renaissance in drawing methods and a very greatly increased respect for graphical methods throughout industry. We have witnessed the phenomenon of many concerns simultaneously developing methods of their own which each has thought a new departure. In general these have only been the discovery, under pressure, of the value of known but neglected methods.

The entire experience of the war points to a great expansion of the field of graphics. It is both an opportunity and a challenge for the Section of Graphics to participate in this development.

ARMY UNIVERSITY

(*Continued from page 262*)

study. Everyone on the staff agreed that they had never taught a more interested or responsive group of students, and what the students thought of the school is best expressed by the phrase we heard repeated many times, "It's the best break we ever got in the Army."

After VJ Day the return of troops to this country was accelerated to a rate that had not been anticipated in the early summer. The Army wished to reduce the number of men in Great Britain to an absolute minimum, and SAU was closed on December 5, after completing two eight-week terms. The school at Biarritz, however, is continuing for a third term and possibly a fourth. There is also the possibility that a semi-permanent establishment of the same sort may be set up in Germany for the benefit of the army of occupation.

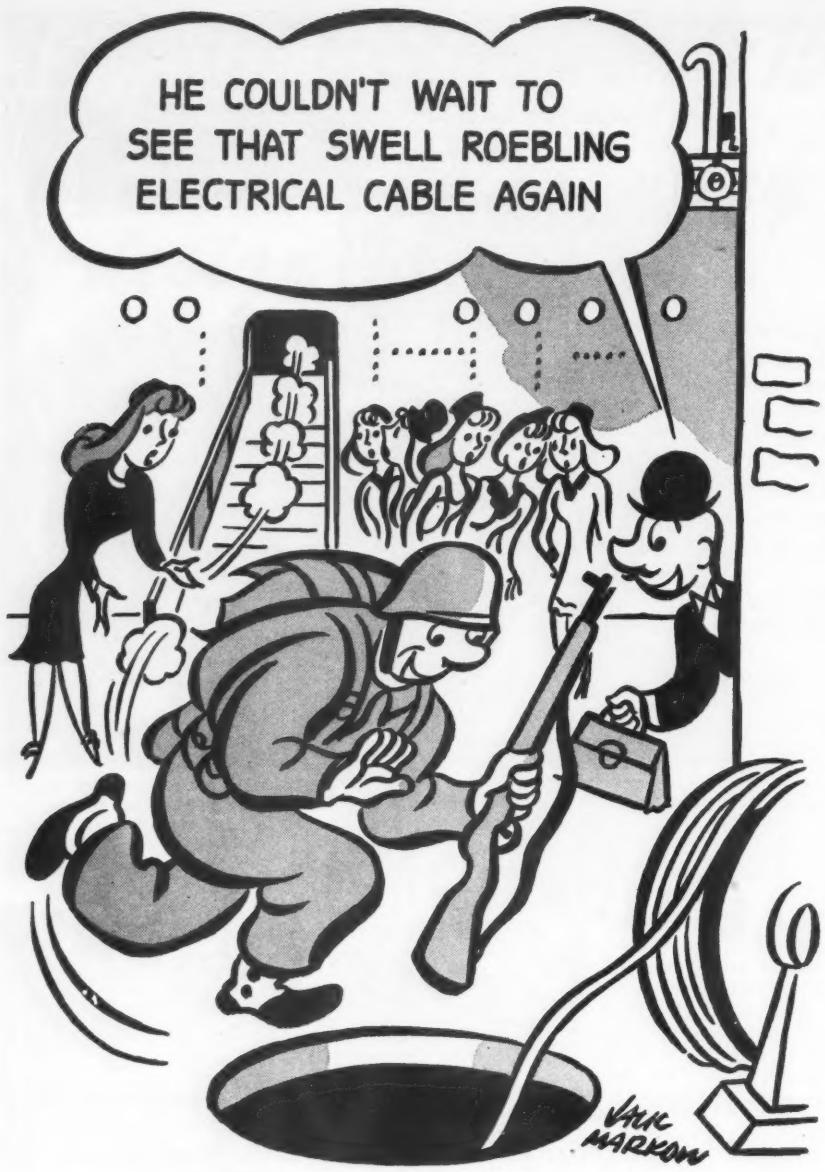
THE FINEST DOUBLE BEDROOM EVER DESIGNED

This is a Budd achievement—a Double Bedroom in which toilet and lavatory have been moved away from the window and placed in an enclosed compartment on the aisle side of the room. This permits a wide, 45-inch panorama window with unobstructed view and gives a privacy which has not been possible before in Double Bedroom accommodations.

The Budd Double Bedroom may also include a shower bath as well as a figure-length mirror and wardrobe. For daytime use there are richly upholstered seats with ample room for three passengers. The two beds are pre-made and may easily be drawn into position by the passengers.

Other new sleeping car accommodations designed by Budd include the low cost Budgette with 32 individual rooms to a car, the compact but luxurious Cabin and the spacious Master Room.

EDWARD G. BUDD MANUFACTURING COMPANY · PHILADELPHIA Budd



Roebling produces every major type of wire and wire product . . . house wire to telephone cable . . . bridge cable to wire rope . . . fine filter cloth to heavy grading screen . . . strip steel and flat wire to round and shaped wire . . . all Roebling products. *All* the result of over 100 years of wire specialization.
John A. Roebling's Sons Company, Trenton 2, N.J.

JR ROEBLING

ROEBLING

PACEMAKER IN WIRE PRODUCTS

WIRE ROPE AND STRAND • FITTINGS • SLINGS • SUSPENSION BRIDGES AND CABLES
COLD ROLLED STRIP • HIGH AND LOW CARBON ACID AND BASIC OPEN HEARTH STEELS
AIRCORD, SWAGED TERMINALS AND ASSEMBLIES • AERIAL WIRE ROPE SYSTEMS • ROUND
AND SHAPED WIRE • ELECTRICAL WIRES AND CABLES • WIRE CLOTH AND NETTING

Briefing the News . . .

(*Continued from page 274*)

placed on the area until all movement ceased.

During the month of February, 1945, nine per cent of the total artillery missions fired by our forces in Germany were on targets located by radar.

General Ingles explained that Signal Corps scientists first learned that radar could detect shells in flight when they built and tested the first American radar in 1937. Studying the ability of the radar to automatically aim antiaircraft guns at target planes, they noticed that the projectiles appeared as echoes on the oscilloscope when they exploded near the targets.

This fact was considered of only casual interest until the Italian campaign, when combat units reported that enemy mortars were causing more casualties than any other one type of weapon. The Army desperately needed a counter-mortar device, and the Signal Corps suggested radar as the answer to this problem.

A large tract of wasteland at Island Beach, New Jersey, was set aside for experimentation and testing of equipment. Combat Infantrymen with extensive mortar experience were detailed to coöperate in the tests. Actual combat conditions were simulated as closely as possible.

When development work was completed, a squad of Infantrymen was directed to simulate a mortar attack, with live ammunition. Their orders were to select a position, fire one round, and then "move out on the double." The first time this routine was followed, their position was located by the radar within two minutes and counter fire was directed with such accuracy that the first round landed within twenty yards of the mortar position.

The modification kit which changed the search radar to a counter-mortar radar was so designed that it could be installed or removed in a matter of minutes. Changes to the equipment involve restricting the scan to sectors of twenty, forty, or sixty degrees instead of a circle; separation of the console from the antenna so it may be installed in a fox hole to protect the operator; elimination of one oscilloscope; and conversion of the remaining Plan Position Indicator oscilloscope so that the center of the sweep is dropped from the center of the scope face to the bottom and the full width of the face can be used in the range spread. — *War Department Release.*

FLAT TO .000012"

THRU "MASS PRECISION" METHODS

One of the jobs currently running through the Nichols Shop specifies lapping hardened steel rings to a flatness of 3 light bands. Measurement with monochromatic light and an optical flat shows all parts coming through to be *flat to one light band —or 11.6 millionths of an inch.*

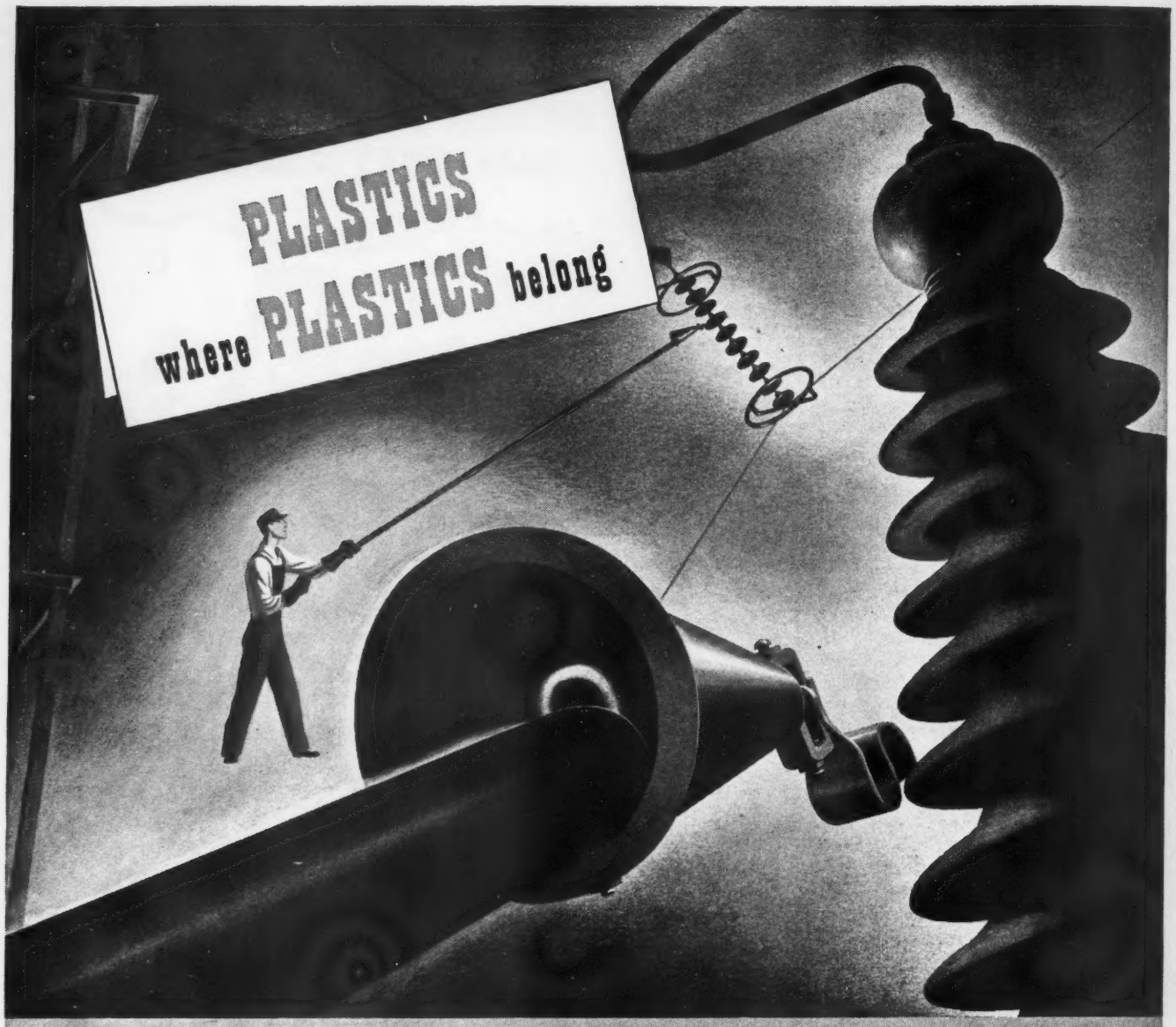
For over 20 years, Nichols has been pioneering in the field of "Mass Precision" lapping. Nichols pioneered finishing parts where two sides had to be flat and parallel, and thickness went to "quarter-tenths". This long, valuable experience has made Nichols versatile . . . now, not only iron and steel, but non-ferrous materials such as bronze and plastic, can be lapped by Nichols to dimensions that are "impossible" for most manufacturers.

Precision lapping can be less expensive than your present finishing methods. It can mean finer tolerances and longer life for parts. It can put your assembly on an interchangeable parts basis. It will pay you to discuss "Mass Precision" methods and costs with our Mr. Harold Lundstrom.

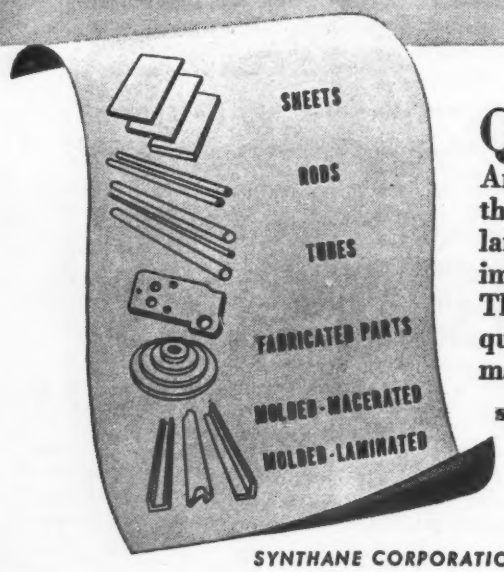
W. H. NICHOLS & SONS, 48 Woerd Avenue, Waltham, Mass.

"Accurate" *Nichols*

PRECISION ENGINEERING AND MANUFACTURING FACILITIES FOR MASS PRODUCTION



Using High Insulation Resistance



QUESTION (and a burning one): "Is the line alive?" Answer: "Yes, if the lamp on the end of 'stick' glows." The lamp works by contact or proximity with high tension lines. The "stick," protecting the inquirer from high voltage, is machined from lengths of Synthane tubing . . . a good example of using plastics where plastics belong.

Synthane has high insulation resistance, resists physical abuse, and its uniformity—vital in this application—can be counted on in quantity manufacture.

SYNTHANE TECHNICAL PLASTICS • DESIGN • MATERIALS • FABRICATION

SYNTHANE CORPORATION, OAKS, PA.

SYNTHANE

Straight talk about your after-college job

No. 3. A successful engineer is entitled to recognition

AS ENGINEERS OURSELVES, we have found that an engineer starting on his first job is aiming for a great deal more in future years than comfort and security for his family.

He wants, and is entitled to *recognition* for himself, his profession and his achievements.

Naturally, a good place to look for assurance that your ability will be recognized is in a company made up largely of engineers. Who else would place so high a value on engineering achievement?

The Timken Roller Bearing Company is such an organization.

Its products, tapered roller bearings, alloy steels and rock bits, require continuous engineering in their manufacture and in their application to hundreds of other products.

■ Most of our executives are engineers. The company in large measure owes its success to engineers. And engineers will have much to do with its future.

That is why our company, each year, is interested in hiring promising students from the country's leading engineering schools. It also explains why we have so much to offer the men selected.

As trainees come in, no effort is made to shape square pegs into round holes. We know that men fresh from universities often possess valuable latent abilities, unknown even to themselves.

■ So we operate a "Work-as-You-Learn" Plan to discover what a man can do best. There are no classes—no theory. Many months may pass before we are satisfied that a man has found himself and is ready for a permanent assignment to work for which he is particularly fitted. But when that time comes, steady advancement usually follows. Besides aptitude, he then brings to his job a broad practical knowledge of our business.

If our plan appeals to you as a sound way to start your career, we would be happy to talk with you in person. We are particularly interested in men who are working for degrees in Metallurgy, Mechanical, Chemical, Mining or Electrical Engineering. Address The Timken Roller Bearing Company, Canton 6, Ohio.

The Timken "Work-as-You-Learn" Plan of Training

FOR BEARING DIVISION

1. Bearing Manufacture
2. Tapered Roller Bearing Design
3. Industrial Application Engineering
4. Automotive Application Engineering
5. Railway Application Engineering
6. Alloy Steel Production and Sales
7. Purchasing Department
8. Field Engineering Service
9. Sales Order Department
10. Sales Engineering in Field

FOR STEEL AND TUBE DIVISION

1. Electric and Open Hearth Melting Shop
2. Steel Rolling Mills
3. Heat Treating (Canton Plant)
4. Bar Finishing and Inspection
5. Tube Finishing, Heat Treating and Inspection
6. Stainless Steel Forge Shop
7. Tool Steel Mill and Forge Shop
8. Production Scheduling Department
9. Metallurgical Laboratory
10. Metallurgical Service (Customer Contacts)

Copyright 1946 by The Timken Roller Bearing Co.

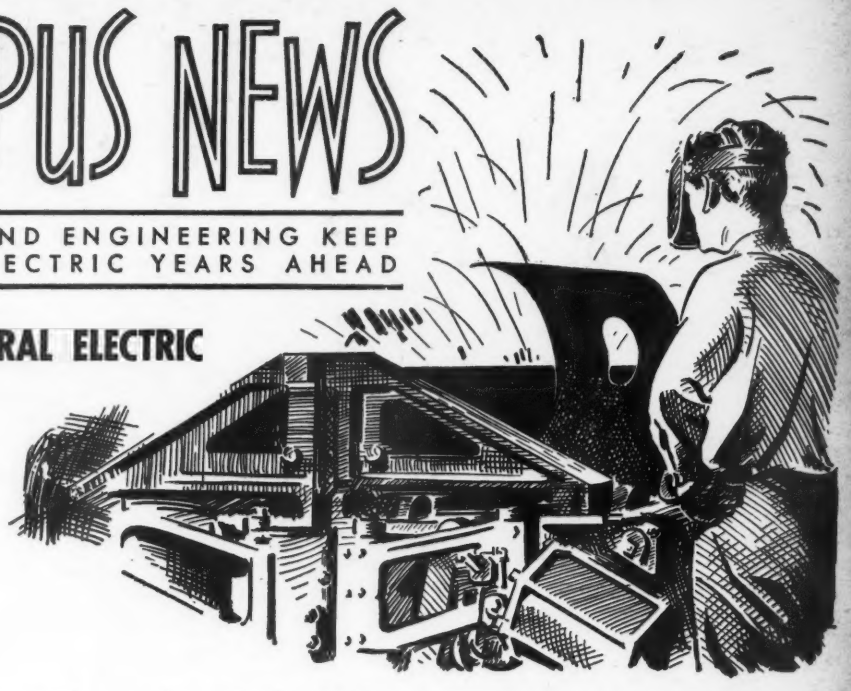
THE TIMKEN ROLLER BEARING COMPANY

PRODUCTS: World's largest manufacturer of *tapered roller bearings*. Specialists and large producers of *fine alloy steels* for industry. Manufacturers of *removable rock bits*. **U.S. PLANTS:** (All in Ohio) Canton, Columbus, Mount Vernon, Wooster and Newton Falls. **FOREIGN ASSOCIATE PLANTS:** British Timken, Ltd., Birmingham, Wolverhampton, Northampton, England; S. A. Francaise Timken, Asnieres (Seine) France. **SALES OFFICES:** In principal cities.

MAR 29 '46
LIBRARY

GE CAMPUS NEWS

RESEARCH AND ENGINEERING KEEP GENERAL ELECTRIC YEARS AHEAD



AIR CONDITIONING AT GENERAL ELECTRIC

NOW that the war is over, many builders and home owners are considering installing some form of air conditioning or automatic heating equipment—or both. Industrial plants are now finding new uses for air conditioning and refrigerating equipment daily; activity in this field was tremendously accelerated during the war. In the light of these conditions, it can be said that a man who is seeking a career should find in this field ample opportunity to learn a business and establish himself.

Heating and Cooling

Air conditioning has grown into a steadily increasing business. In spite of the depression of the early thirties and the expense of making and installing equipment, General Electric and other manufacturers showed their confidence in air conditioning by developing and placing on the market many kinds of air conditioning equipment from giant units for stores and theaters to small units for room conditioning.

Paralleling the development of gas and oil as furnace fuels was the development of furnace electrical control systems. The market for automatic heating will be huge. Commercial refrigeration will be important as long as people want food to eat. And commercial air conditioning will continue to find new uses.

"Slide Rule" or Sales Engineering

Manufacturers need good engineering talent—for designing, application, and for commercial engineering activities. If a man feels that he has some talent for influencing people as well as manipulating a slide rule, he might consider becoming a sales engineer, selling air conditioning and refrigerating machinery, or becoming an installation and service manager.

The sale of air conditioning and refrigeration equipment to factories and mills has always required competent sales and application engineers. Here the market is expanding so rapidly that contractors may find it advisable to consider the use of "practical" engineers who have apparent but unpracticed sales ability.

The scope of activity is very broad, and hundreds of opportunities will be open for both experienced and inexperienced men. *This advertisement is one of a series discussing opportunities for young men in fields in which General Electric has made important contributions. General Electric Co., Schenectady, N. Y.*

GENERAL ELECTRIC

963-111C-211

The Murray Printing Company
Cambridge, Massachusetts